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# THE ELEMENTS

OF

# CHEMICAL ARITHMETIC

WITH

## A SHORT SYSTEM OF ELEMENTARY QUALITATIVE ANALYSIS.

BY

J. MILNOR COIT, PH.D.,
MASTER IN ST. PAUL'S SCHOOL, CONCORD, N.H.

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# PREFACE.

THIS little manual is intended to supplement the teaching of the text-books of descriptive chemistry, and to be used as a companion to them, by those who desire to make the whole subject more practical. It is the result of the author's experience after several years of elementary science teaching.

Part I. contains some of the more important rules and principles of chemical arithmetic, followed by a series of problems, which will not be found to be above the comprehension of the average student in the schools. The matter relating to chemical theory, and the rules, have been collected from the best authorities.

Part II. is devoted to an elementary system of qualitative analysis, and the best methods have been adopted. This part of the book can be used separately, and can be taught together with any good work in descriptive chemistry, such as Eliot & Storer's, Shepard's, Remsen's, or Avery's Chemistry. An intelligent student can, with the occasional supervision of his instructor, work out by himself the reactions and the separations as given in the tables. The tables are those generally in use. Tests are given for the more common metals and acids only, and the reagents indicated are those which almost any school laboratory will afford.

J. M. C.

St. Paul's School,
Concord, N.H.

# PART I.

# CHEMICAL ARITHMETIC.

## CHAPTER I.

### INTRODUCTION.

**1. Matter** is anything that occupies space.

**2. Divisions of Matter.** Three divisions of matter are recognized in science, — masses, molecules, and atoms.

A *mass* of matter is any portion of matter appreciable by the senses.

A *molecule* is the smallest particle of matter into which a body can be divided without losing its identity; or it is the smallest portion of matter which can exist by itself.

An *atom* is a still smaller particle produced by the division of a molecule; or it is the smallest portion of matter that can go into combination.

EXAMPLES. The sun and a grain of sand are masses of matter. The smallest particle of salt which can exist and which exhibits the properties of salt is a molecule. The minute particles of chlorine and sodium which compose the molecule of salt are atoms.

A mass is made up of molecules, and a molecule is composed of atoms.

**3. Attractions of Matter.** The three forms of attraction admitted in science are: —

First. *Gravitation*, or the attraction between masses.

Second. *Cohesion*, or the attraction between like molecules; adhesion between unlike molecules.

Third. *Chemical attraction*, or the attraction between unlike atoms.

EXAMPLES. The attraction between the sun and the planets, or between the earth and all bodies upon it, is *gravitation.* The attraction between the molecules of a piece of marble is *cohesion.* The attraction between a liquid and solid, — as, for instance, when you dip your hand into water it becomes wet, — or between two different solids at the surface, as shown by the action of cements, is *adhesion.* The attraction between the unlike atoms of chlorine and sodium by means of which we have an entirely different substance, salt, is *chemical attraction.*

**4. Province of Physics.** Physics is that department of physical science which studies the results which come from the molar and molecular conditions of matter.

**5. Province of Chemistry.** Chemistry studies matter in its atomic condition. It investigates the laws and conditions of chemical changes, and seeks to account for some of the phenomena connected therewith.

**6. Physical Changes.** Physical changes are those which take place outside the molecule; they have no effect upon the molecule itself nor alter the identity of the matter operated on. The study of physics is a study of physical changes.

**7. Chemical Changes.** Chemical changes take place through the atoms and within the molecule. They alter the character of the molecule, and hence destroy the identity of the matter itself. The study of chemistry is a study of chemical changes.

EXAMPLES. The change of water into ice and steam, or the change of any solid into a liquid, or of any liquid into a vapor, are *physical changes.* But when water is subjected to the influence of the electric current, it undergoes a more radical change; the water disappears, and in its place appear two gaseous substances, oxygen and hydrogen, entirely different from the water from which they were derived. This is a *chemical change.*

**8. Physical Properties.** Physical properties are those properties which bodies possess in virtue of their molar or molecular condition.

**9. Chemical Properties.** Chemical properties are those which result from the atomic composition of the molecule.

**10. Chemistry defined.** Chemistry is that branch of physical science which treats of the atomic composition of bodies, and of those changes in matter which result from an alteration in the kind, the number, or the relative position of the atoms which compose the molecule.

**11. Analysis and Synthesis.** The two processes by which the chemist seeks to find out the composition of matter are analysis and synthesis.

*Analysis* consists in separating the molecule into its constituent atoms.

*Synthesis* consists in putting together constituent atoms to form the molecule.

# CHAPTER II.

## MOLECULES AND ATOMS.

**12. Chemical Definition of the Molecule.** A molecule is the smallest particle of any substance which can exist in a free state in nature.

**Molecules classified.** Molecules are of two classes:—

First. *Elementary molecules*, or those whose atoms are alike.

Second. *Compound molecules*, or those whose atoms are unlike.

**13. Simple Substances** are those whose molecules contain like atoms.

**14. Compound Substances** are those whose molecules contain unlike atoms.

**15. Number of Simple Substances.** There are sixty-eight elementary substances, as far as has been investigated by chemical science; that is, sixty-eight substances whose molecules contain like atoms. Therefore it is obvious that there are sixty-eight different kinds of atoms. From combinations of these sixty-eight kinds of atoms all the different varieties of matter result. We cannot resolve a simple substance into any other substances or atoms.

**16. Ampère's Law.** "Equal volumes of all gases, simple as well as compound, under like conditions of temperature and pressure, contain the same number of molecules."

From this law, which is the most important law of modern chemistry, it results, —

*First.* That the molecules of all bodies in the gaseous state are of the same size.

*Second.* That the weight of any molecule, compared with that of hydrogen, is proportional to the weight of any given volume, also compared with the same volume of hydrogen.

EXAMPLES. If 1 liter of nitrogen, which weighs 14 times as much as a liter of hydrogen, contains the same number of molecules, then it is obvious that each molecule of nitrogen must be 14 times as heavy as a molecule of hydrogen.

**17. Number of Atoms in the Molecule of Hydrogen.** Assuming that 1 volume of hydrogen contains 1000 molecules, then, according to the law of Ampère, 1 volume of chlorine will contain 1000 molecules also.

Suppose these volumes (that is, 1 volume of hydrogen containing 1000 molecules and 1 volume of chlorine containing 1000 molecules) be mixed together and exposed to the action of the sunlight, they combine, forming 2 volumes of the new substance, hydrochloric acid gas, which 2 volumes, by the same law, will contain 2000 molecules. Upon analysis, each molecule of hydrochloric acid gas will be found to contain 1 atom of hydrogen and 1 atom of chlorine. That is, the 2000 molecules will contain 2000 atoms of hydrogen and 2000 atoms of chlorine. The 2000 molecules will contain, therefore, 4000 atoms; or, each molecule will contain 2 atoms. Hence each molecule of hydrogen is made up of 2 atoms.

**18. Molecular Weights.** If the weight of the hydrogen atom be taken as 1, then, since its molecule contains 2 atoms, its molecular weight will be 2.

Since the molecule of a compound gas or vapor occupies a volume twice as large as that occupied by the atom of hydrogen, it is obvious that the specific gravity of the gas or vapor may be found from the molecular weight by dividing the latter by 2. The *specific* gravity of a compound gas or vapor is, therefore, one-half its molecular weight. The molecular weight of any substance may be obtained by multiplying its density in the state of gas by the molecular weight of hydrogen; that is, by 2.

EXAMPLES. The density of oxygen gas, for example, is 16; that is, any volume as 1 liter weighs 16 times as much as 1 liter of hydrogen. Its molecule must be, therefore, 16 times as heavy. The molecular weight of hydrogen is 2; therefore the molecular weight of oxygen will be $16 \times 2 = 32$.

The weight of 1 liter of hydrogen is called 1 crith, and the weight of the hydrogen atom 1 microcrith.

**19. Number of Atoms in the Molecule.** The number of atoms in a molecule is obtained by dividing the molecular weight by the atomic weight.

EXAMPLE. The molecular weight of oxygen is 32, and its atomic weight 16. The number of atoms in the molecule is 32 divided by $16 = 2$. The molecular weight of phosphorus is 124, and its atomic weight 31; its molecule, therefore, contains 4 atoms.

## PROPERTIES OF ATOMS.

**20. Definition.** An atom is the smallest particle of simple matter which can enter into the composition of a molecule.

**21. Atomic Weight.** The relative weight of any atom referred to hydrogen as unity is its atomic weight. It is the smallest weight of any simple substance which can take part in the formation of a chemical compound.

The molecular weight of any substance is the sum of the weights of its constituent atoms.

**22. Quantivalence.** The quantivalence of an atom is the quality of its combining power, expressed in hydrogen units. It expresses the number of hydrogen atoms with which it can combine or for which it can be exchanged.

EXAMPLES. The quantivalence of zinc is 2, because 1 atom replaces 2 of hydrogen. The quantivalence of carbon is 4, because 1 atom of carbon requires 4 of hydrogen to satisfy it in combination. Atoms are called monads, dyads, triads, tetrads, pentads, hexads, and heptads, according to their quantivalence. The Latin numerals are used for the adjective terms. These atoms are univalent, bivalent, trivalent, quadrivalent, quinquivalent, sexivalent, and septivalent. Atoms whose quantivalence is even are called *artiads*; those whose quantivalence is odd are called *perissads*.

An atom may form several compounds with the same substance. Therefore its quantivalence may vary. It always increases or diminishes by 2, so that it may have quantivalence of 1, 3, 5, or 7, or of 2, 4, or 6. A perissad atom can never become an artiad by such a change, nor can an artiad become a perissad.

EXAMPLES. Iron in iron sulphate is a dyad, in pyrites it is a tetrad, and in ferric acid a hexad. Chlorine forms a series of compounds with oxygen in which its quantivalence is 1, 3, 5, and 7.

Atoms are divided into two classes, according to the quality of their combining power.

First. *Positive atoms* are those which are attracted to the negative pole in electrolysis, and whose hydrates are bases.

Second. *Negative atoms* are those which go to the positive electrode, and whose hydrates are acids.

**23. Atomic Symbols.** Berzelius, in 1815, proposed an abbreviated form of chemical language. In this system each atom has for its symbol the first letter of its Latin name. When the names of two different atoms begin with the same letter, a second letter suggestive of the name is added.

EXAMPLES. Ag stands for an atom of silver; Fe, for an atom of iron; Sn, for one of tin, etc. (on page 89 will be found the table of the symbols of the elements).

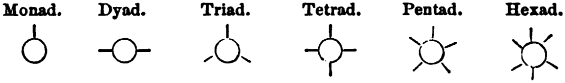
Each atomic symbol stands not only for the atom, but represents its atomic weight.

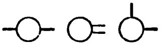
EXAMPLES. Fe (ferrum) represents 56 weight-units of iron; Hg (hydrargyrum), 200 weight-units of mercury; O, 16 weight-units of oxygen.

**24.** The quantivalence of an atom is indicated by placing Roman numerals above or a little to the right of the symbol. Sometimes minute-marks are used.

EXAMPLES. 1. H or $H'$ stands for the monad hydrogen atom; 2. S or $S''$ stands for the bivalent sulphur atom; 3. P or $P'''$ for the trivalent phosphorus atom; 4. C or $C''''$ for the quadrivalent carbon atom.

Sometimes graphic symbols are used to represent the quantivalence atoms, the graphic symbols being a circle with lines called bonds radiating from it; as, for example,



The circles are usually omitted, the bonds radiating from the symbol. The number of bonds and not their direction is significant, as, for example,  stands equally for 1 atom of dyad oxygen. $N\equiv$, $\overset{|}{N}=$, or $-N=$ equally represent the atom of trivalent nitrogen.

**25. Multiplication of Atoms.** Atoms are multiplied by placing an Arabic numeral below and to the right of the symbol.

Examples. $C_2$ represents 2 atoms of carbon. $N_4$, 4 atoms of nitrogen. $Cl_3$, 3 atoms of chlorine.

Molecules are multiplied by enclosing their symbols in brackets and placing the numeral outside, below, and to the right.

Examples. $(H_2)_6$ represents 6 molecules of free hydrogen. $(Br_2)_2$ stands for 2 molecules of bromine.

# CHAPTER III.

## COMPOUND MOLECULES AND VOLUME RELATIONS.

**26. Compound Molecule.** A compound molecule is one whose constituent atoms are unlike. Compound molecules are formed by the union of atoms according to the law of quantivalence.

**27. Molecular Weight.** The molecular weight of a compound molecule is the sum of the atomic weights of its constituents. It is always equal to twice the density of the substance in the state of gas.

**28. Classification of Compound Molecules.** Compound molecules are divided into two classes: first, those whose atoms are directly united, called Binaries; second, those whose atoms are indirectly united, called Ternaries. A binary compound is formed by the union of two simple substances, the termination IDE being the characteristic: as, for example, sodium and chlorine yield sodium chloride; silver and sulphur yield silver sulphide; calcium and iodine yield calcium iodide. In some cases the number of atoms of each constituent is to be indicated.

This is done by prefixing Greek numerals to each of the names given; as, for example, 1 atom of C and 2 of O form carbon dioxide, 1 atom of P and 5 of Br form phosphorus pentebromide.

**29. Definition of an Acid.** An acid molecule is one which consists of one or more negative atoms united by hydrogen and oxygen. It is a compound of hydrogen and oxygen with some non-metallic element, and possesses the property of turning blue litmus paper or solution red.

**30. Definition of a Base.** A basic molecule is one which contains one or more positive atoms united by hydrogen and oxygen. It is a compound of hydrogen, oxygen, and some metallic element, and possesses the property of restoring the color to vegetable blues, which have been reddened by an acid.

**31. Definition of a Salt.** A saline molecule is one which contains a positive atom or group of atoms, united by oxygen to a negative atom or group of atoms. It is formed by the action of an acid upon a base, and since it contains no hydrogen, has no action upon vegetable colors.

**32. Compound Radical.** A compound radical is a group of atoms, which goes into combination like a single atom. It may be composed of two or more elements; as, for example, ($NH_4$) ammonium, ($C_2H_5$) ethyl.

**33. Normal, Acid, Basic, and Double Salts.** A salt is formed by substituting a metal for the hydrogen of an acid, each bond of the metal displacing one atom of hydrogen. A normal salt is formed by displacing all the hydrogen of the acid with an equivalent metal. An acid salt is formed by exchanging a part of the hydrogen of an acid for an equivalent of metal.

A basic salt is formed by the substitution of a metal in part for the hydrogen of an acid, and in part for the half or the whole of the hydrogen of water ($H_2O$).

Double salts are those containing two or more different positive or metal atoms.

**Examples.** $K'$ with $HNO_3$ forms $KNO_3$, displacing H. $KNO_3$ is a normal salt, formed also by acting upon $HNO_3$ by KHO, as: —

$$HNO_3 + KHO = KNO_3 + H_2O.$$

$K'$ with $H_2SO_4$ may form $KHSO_4$, an acid sulphate formed also by

$$KHO + H_2SO_4 = HKSO_4 + H_2O.$$

$Bi'''$ with $\left\{ \begin{matrix} HNO_3 \\ H_2O \end{matrix} \right.$ forms $Bi \left\{ \begin{matrix} NO_3 \\ O \end{matrix} \right.$, usually written $BiONO_3$, a basic nitrate.

$NaCa''SbO_4$, sodio-calcium antimonate is an example of a double salt, or $Ba''Zn''SiO_4$, baro-zincic silicate.

Monobasic acids can form only normal salts. Polybasic acids can form normal, acid, and double salts.

**34. Chemical Equations.** A chemical equation is the expression in symbols of a chemical reaction, or change. The sign plus (+) indicates *added to*, and the sign minus (−), *taken from*, and the sign of equality (=), *equals to*. The equation must be a true equation; that is, the sum of the weights of the atoms on one side must equal the sum of the weights of the atoms on the other side.

**35.** The substances entering into the reaction are called factors; these constitute the first member. The substances issuing from the reaction are called products; these constitute the second members.

The equation, representing the reaction of two molecules upon each other may be written by the following rule: —

Place the formulas of the factors, connected by the sign plus, as the first member of the equation, and the formulas of the products, also connected by the sign plus, as the second.

EXAMPLES. Let $AB$ and $EF$ be two molecules. The reaction between them would be represented by the equation

$$AB + EF = AF + BE.$$

**36. Weight of the Factors and Products.** The quantities of matter taking part in a chemical change are definite in weight, since each formula represents a definite weight, viz., the molecular weight. For the same reason no loss of weight can be the result of any chemical reaction.

**37.** There are three kinds of chemical reactions:—

*First.* Analytical reactions; that is, the separation of a complex molecule into simpler ones.

*Second.* Synthetical reactions, or the union of two or more simple molecules to form a more complex one.

*Third.* Metathetical reactions, or the transposition or exchange of atoms between molecules.

EXAMPLES. An *analytical reaction* may be represented by the general equation

$$EF = E + F;$$

or, taking an actual example,

$$\underset{\text{Mercuric oxide.}}{\mathrm{HgO}} = \underset{\text{Mercury.}}{\mathrm{Hg}} + \underset{\text{Oxygen.}}{\mathrm{O}};$$

that is, one molecule of mercuric oxide will yield one molecule of mercury and one molecule of oxygen.

*Synthetical reactions* may be represented by the general equation

$$E + F = EF;$$

or, taking an actual example,

$$\underset{\text{Iron.}}{\mathrm{Fe}} + \underset{\text{Sulphur.}}{\mathrm{S}} = \underset{\text{Iron sulphide.}}{\mathrm{FeS}};$$

that is, one molecule of iron and one molecule of sulphur yield one molecule of iron sulphide.

*Metathetical reactions* may be represented by the general formula

$$AB + EF = AF + BE;$$

or, practically,

$$\underset{\text{Zinc}}{Zn} + \underset{\text{Sulphuric acid}}{H_2SO_4} = \underset{\text{Zinc sulphate}}{ZnSO_4} + \underset{\text{Hydrogen.}}{2H.}$$

**38.** The conditions which form chemical change depend upon the facility with which the atoms of any molecule may be rearranged. When substances are in the gaseous or liquid state, these changes between atoms take place most readily. Hence, fusion or solution or vaporization facilitate chemical action. Heat is therefore the great aid to the chemist.

# CHAPTER IV.

## STOICHIOMETRY.—CHEMICAL ARITHMETIC.

**39. Definition.** By Stoichiometry we mean that department of chemistry which treats of the numerical relations of atoms. The calculations of these numerical relations, whether of volume or weight, depend upon the fact that every atom has its own weight, called the atomic weight. The atomic weight is the smallest portion by weight of any simple or elementary substance—referred to the atom of hydrogen as unity—which can take part in a chemical change.

**40. Unit of Weight.** The weight of the hydrogen atom is called a microcrith. (The weight of one liter of hydrogen under general conditions of temperature and pressure is one crith.) We adopt the term microcrith for convenience' sake.

**41.** All chemical changes take place between definite quantities of matter, as represented by a chemical equation. An equation expresses not only the fact of chemical reaction between two bodies, but also indicates the quantities by weight concerned in it.

### RULES.

**42. From the Formula of a Substance to find its Molecular Weight.** The molecular weight of a compound is the sum of the atomic weights of all the atoms of the elements which compose it.

The name of each element present being written in a column, and opposite to each the multiple of its atomic weight which is present in the compound, on adding these numbers together the molecular weight of the compound is obtained.

Thus the molecular weight of sulphuric acid, $H_2SO_4$, is

$$\begin{array}{l}
H = \phantom{0}1 \times 2 = \phantom{0}2 \\
S = 32 \times 1 = 32 \\
O = 16 \times 4 = \underline{64} \\
\qquad\qquad\qquad 98
\end{array}$$

**43. To find the Percentage Composition of any Substance in a Molecule.** *Rule.* Multiply the atomic weight by the number of atoms, and this product by 100. Divide the final product by the molecular weight, and the quotient will be the percentage amount of that constituent.

Example. What is the percentage composition of carbon dioxide, $Co_2$?

$$\begin{array}{ll}
\text{Carbon} & = 12 \\
\text{Oxygen, } 16 \times 2 & = \underline{32} \\
\text{Molecular weight,} & \phantom{=}\ 44
\end{array}$$

$$\text{Carbon} = 12 \times \tfrac{100}{44} = 27.27 \text{ per cent.}$$
$$\text{Oxygen} = 32 \times \tfrac{100}{44} = 72.73 \text{ per cent.}$$

This rule can be expressed by a general formula. Let $m$ represent the molecular weight, $a$ the atomic weight of any constituent, $n$ the number of atoms, and $x$ its percentage amount; then we have the proportion: —

$$m : an :: 100 : x,$$

from whence the formula

$$x = \frac{an \times 100}{m}. \qquad (1)$$

In the above formula, when any three of the quantities $a$, $n$, $m$, and $x$ are known, the fourth can be found. Whence, to find the number of atoms of any constituent in a molecule, "$x$," "$a$," and "$m$" being known, we have, by transposing formula (1): —

$$n = \frac{mx}{100a}, \qquad (2)$$

also

$$a = \frac{mx}{100n}, \qquad (3)$$

and

$$m = \frac{an \times 100}{x}. \qquad (4)$$

**44. To calculate from an Equation a Mass.**

*Rule.* Find the multiples of the atomic or molecular weights of the substances given and asked in the equation, and work the proportion.

The molecular weight of substance given : the molecular weight of substance asked : : the real mass of substance given : the real mass of substance asked. Thus, to find now many grams of sodium sulphate can be obtained from 100 grams of sodium hydrate: —

EXAMPLE 1. $2\,NaHO + H_2SO_4 = 2\,H_2O + Na_2SO_4.$

$2 \times 40 \qquad\qquad\qquad\qquad 142.$

$2 \times 40 : 142 :: 100 : x$

$x = \frac{14200}{80} = 177.5$ grams.

EXAMPLE 2. In the equation

$$KNO_3 + H_2SO_4 = HNO_3 + HKSO_4$$
$$101 + 98 = 63 + 136.$$

125 grams of $KNO_3$ yield 77.97 grams of $HNO_3$, whose molecular weight is 63. What is the molecular weight of $KNO_3$?

This rule can be simply expressed by the general proportion: —

$$M : m :: W : w,$$

where $M$ represents the molecular weight of the substance given, $m$ the molecular weight of the substance asked, $W$ the real mass of the substance given, and $w$ the real mass of the substance asked; whence

$$M = \frac{mW}{w}, \tag{1}$$

$$W = \frac{Mw}{m}, \tag{2}$$

$$m = \frac{Mw}{W}, \tag{3}$$

$$w = \frac{mW}{M}. \tag{4}$$

**45. The Relations of Weight to Volume.** 1. To find the volume occupied by a given weight of any gas. *Rule.* Divide the weight of the gas given by the weight of 1 liter; the quotient is the number of liters.

2. To find the weight of any given volume of gas. *Rule.* Multiply the number of liters of gas by the weight of 1 liter; the product is the weight of the given volume.

EXAMPLES. 1. What volume is occupied by 6.08 grams of oxygen, the weight of 1 liter of oxygen being 1.43 grams? $6.08 \div 1.43 = 4.25$ liters. *Ans.*

2. What is the weight of 25 liters of nitrogen gas, 1 liter weighing 1.26 grams? $1.26 \times 25 = 31.5$ grams. *Ans.*

**46. Density of Gases.** The density of any gas expresses how many times the gas is heavier than hydrogen. Knowing the density, the weight of 1 liter may readily be obtained by multiplying it by the weight of 1 liter of hydrogen, 0.0896 grams, or 1 crith. The molecular weight of any substance being the weight of 2 volumes of the substance in the state of gas, it is evident that its density in the state of gas may be obtained by dividing its molecular weight by 2. With few exceptions, the density of any elementary gas is expressed by the same number as its atomic weight, and that of any compound gas is expressed by the same number as half its molecular weight. Thus, oxygen, $O = 16$; density, 16; or 1 liter weighs 16 criths. Ammonia, $NH_3 = 17$; density, 8.5; or 1 liter weighs 8.5 criths.

**47. Relation of Gaseous Volume to Pressure.** To calculate the change in volume of a mass of gas produced by a change in pressure.

*Boyle's Law.* The volume of a mass of gas varies inversely as the pressure upon it; or the volume of a mass of gas, multiplied by the pressure at any one time, is equal to the volume of the same mass of gas multiplied by the pressure upon it at any other time. Thus, let $V$ equal the volume of a gas under the pressure $P$, and let $V'$ equal the volume under the pressure $P'$; then

$$VP = V'P', \text{ or } V = \frac{V'P'}{P}.$$

If the pressure upon 1000 cc. of gas be increased from 400 mm. to 800 mm., what is the new volume?

$$V = \frac{1000 \times 400}{800} = 500 \text{ cc.}$$

**48. Relation of Gaseous Volume to Temperature.** *Guy Lussac's Law.* When 273 volumes of gas at 0° C. are heated, they increase by one volume for every 1° C. through which they are heated. Thus:—

273 volumes of gas at 0° C. become at 1° C. 273 + 1 volumes,
273 " " " " " 2° C. 273 + 2 "
273 " " " " " 3° C. 273 + 3 "
273 " " " " " $t$° C. 273 + $t$ "

where $t$ expresses any number of degrees on the centigrade scale.

The coefficient of the expansion of a gas is $\frac{1}{273}$ of the volume of the gas at 0° for every degree centigrade. Hence $v$ volumes at $t$° C. become at $T$° C.

$$v \times \frac{273 + T}{273 + t}$$

volumes; which, if $V$ stands for the volume of the gas after change of temperature $t$° C. to $T$° C., is usually written:—

$$V = \frac{v(273 + T)}{273 + t}.$$

Example 1. Find the new volume, if 1000 cc. of gas are heated from 17° C. to 27° C. The formula is:—

$$V = \frac{1000\,(273 + 27)}{273 + 17} = \frac{1000 \times 300}{290} = 1034.8 \text{ cc.}$$

Example 2. If 1000 cc. of gas at − 23° C. are heated to 27° C., find the new volume.

$$V = \frac{1000\,(273 + 27)}{273 - 23} = \frac{1000 \times 300}{250} = 1200 \text{ cc.}$$

**49.** If the pressure on the gas, as well as its temperature, be changed, the above formula must be combined with the one given in (46).

$$V = \frac{v(273 + T)}{273 + t} \times \frac{P'}{P}.$$

EXAMPLE. If 500 cc. of gas are cooled from 39° C. to 13° C., the pressure being decreased from 800 mm. to 300 mm., find the new volume.

$$V=\frac{500\,(273+13)}{273+39}\times\frac{800}{300}=1222.2 \text{ cc.}$$

**50. Density of Gases.** When the temperature of and the pressure on a gas are not mentioned, it is supposed to be at 760 mm. and 0° C. A gas under these conditions is said to be normal.

The formulæ given in this and the succeeding section only apply to normal gases; hence, when necessary, the gas under consideration must be rendered normal by using the formula: —

$$V=\frac{v\times 273}{273+t}\times\frac{P'}{760},$$

and, conversely, the volume found by these formulæ is normal, and must be reduced to the required temperature and pressure by

$$V=\frac{v\,(273+T)}{273}\times\frac{760}{P}.$$

In the case of gases, the liter, = 1000 cc., is taken as the unit of volume, and the mass of one liter of normal hydrogen, called a crith, = .0896 gram, is taken as the unit of mass.

The density of a gas, then, is the number of criths contained in one liter of it, measured at 0° C. and 760 mm.; or the number of times it is heavier than an equal volume of hydrogen.

Hence the mass in grams of a liter of any normal gas can be found by multiplying its density by .0896.

EXAMPLE. The density of carbon monoxide is 14; required the weight of one liter.

$$14 \times .0896 = 1.2544 \text{ grams.}$$

The density of a gas referred to air may be obtained by multiplying its density referred to hydrogen by .06926, the density of hydrogen referred to air.

EXAMPLE. Nitric oxide is 15 times as heavy as hydrogen; how many times is it heavier than air?

$$15 \times .06926 = 1.0389.$$

If the density of a gas referred to air be given, its density referred to hydrogen can be obtained by multiplying its density referred to air by 14.436.

EXAMPLE. Sulphur dioxide is 2.22 times as heavy as air; find its density and molecular weight.

$$14.436 \times 2.22 = 32.042$$

is the density referred to hydrogen, and

$$32.042 \times 2 = 64.084$$

is the molecular weight.

**51. Volume and Mass of Gases.** It is found by experiment that 22.32 liters of any normal gas weigh a number of grams equal to the number expressing the molecular weight of the gas. Thus: —

| | | | | | | |
|---|---|---|---|---|---|---|
| 22.32 | liters | of | hydrogen | ($H_2 = 2$) | weigh | 2 grams. |
| 22.32 | " | " | oxygen | ($O_2 = 32$) | " | 32 " |
| 22.32 | " | " | nitrogen | ($N_2 = 28$) | " | 28 " |
| 22.32 | " | " | chlorine | ($Cl_2 = 71$) | " | 71 " |

This volume, 22.32 liters, is commonly spoken of as "two volumes" and expressed by the symbol □□.

Since 22.32 liters (or, if great accuracy be not required, 22.4 liters) of any gas weigh its molecular weight in grams, a liter of any gas weighs its molecular weight in grams divided by 22.32 (or 22.4); and one gram of any gas occupies 22.32 (or 22.4) liters divided by its molecular weight. Hence the mass in grams of any volume of a gas can be found by multiplying the number of liters of it by its molecular weight, and dividing by 22.32.

EXAMPLE 1. Find the mass of 250 liters of chlorine ($Cl_2 = 71$).

$$\frac{250 \times 71}{22.32} = 795.25 \text{ grams.}$$

Conversely, the volume in liters of any gas can be found by multiplying the number of grams of it by 22.32, and dividing by the molecular weight.

EXAMPLE 2. Find the volume of 225 grams of hydrogen sulphide ($H_2S = 34$).

$$\frac{225 \times 22.32}{34} = 147.7 \text{ liters.}$$

EXAMPLE 3. Find the mass of 80 liters of oxygen ($O_2 = 32$) measured at 52° C. and 740 mm. The gas must be reduced to 0° C. and 760 mm.

$$\frac{80 \times 273}{273 + 52} \times \frac{740}{760} \times \frac{32}{22.4} = \frac{8880}{95} = 93.47 \text{ grams.}$$

**52. Equation and Volumes of Gases.** When the volume of one gas is given, and that of another gas is asked, since each molecular weight expresses two volumes of the gas, the result may often be obtained directly.

**Example 1.** What volume of hydrogen chloride is formed when 10 liters of chlorine combine with hydrogen?

$$Cl_2 + H_2 = 2\,HCl.$$
$$\square\square + \square\square = 2\,\square\square$$

Two volumes of chlorine form twice two volumes of hydrogen chloride; hence 10 liters of chlorine form 2 × 10 = 20 liters of hydrogen chloride.

**Example 2.** If 10 liters of hydrogen at 15° C. are burned, what volume of steam at 300° C. is formed?

$$H_2 + O = H_2O.$$
$$\square\square \quad \square \quad \square\square$$

The volume of the steam would be equal to that of the hydrogen, if the temperatures were the same, making the correction for the change of temperature.

$$V = \frac{10\,(273 + 300)}{273 + 15} = \frac{5730}{288} = 19.895 \text{ liters.}$$

When the mass of a solid or liquid is given or asked, and the volume of a gas is asked or given, the equation can only be solved in terms of the mass of the gas.

**Example 3.** How much lead sulphide can be precipitated by 17 liters of hydrogen sulphide?

$$\underset{34}{H_2S} + PbN_2O_6 = 2\,HNO_3 + \underset{239}{PbS}.$$

17 liters of $H_2S$ weigh $\frac{17 \times 34}{22.4}$ grams.

34 grams of $H_2S$ precipitate 239 grams of lead sulphide.

1 gram of $H_2S$ precipitates $\frac{239}{34}$ grams of PbS.

$\frac{17 \times 34}{22.4}$ grams of $H_2S$ precipitate

$$\frac{17 \times 34}{22.4} \times \frac{239}{34} = 181.3 \text{ grams of lead sulphide.}$$

**53. Gaseous Diffusion.** *Graham's Law.* "The velocity of the diffusion of any gas is inversely proportional to the square root of its density." This law applies of course to volumes. That is, when two gases diffuse through the same apparatus for equal times under similar conditions, the volume of the one gas diffused multiplied by the square root of its density is equal to the volume of the other gas diffused multiplied by the square root of its density.

$$V\sqrt{D} = v\sqrt{d}.$$

EXAMPLE. 4 liters of hydrogen diffuse through an apparatus in 10 minutes, and 1 liter of oxygen in an equal time under similar conditions; find the density of oxygen.

$$1\sqrt{D} = 4\sqrt{1}, \qquad \therefore\ D = 16.$$

## EXAMPLES.

### MOLECULAR WEIGHTS.

1. Find the molecular weight of (*a*) carbon monoxide, $CO$; (*b*) magnesia, $MgO$; (*c*) lime, $CaO$; (*d*) alumina, $Al_2O_3$.

2. Find the percentage of oxygen in each of the above-mentioned bodies.

3. Find the molecular weight of (*a*) nitric oxide, $NO$; (*b*) sodium hydrate, $NaHO$; (*c*) ferric oxide, $Fe_2O_3$.

4. Find the molecular weight of (*a*) zinc sulphate, $ZnSO_4 . 7\,H_2O$; (*b*) copper sulphate, $CuSO_4 . 5\,H_2O$; (*c*) sodium sulphate, $Na_2SO_4 . 10\,H_2O$.

### THE VOLUME OF A MASS OF GAS.

1. 1000 cc. of gas are heated from 0° to 39°. Find the new volume.

2. 1000 cc. of gas are heated from 39° C. to 52° C. Find the new volume.

3. The pressure on 10 cc. of gas is 7 meters; if the pressure be reduced to 847 mm., what is the new volume?

4. 1000 cc. of air at 13° C. occupy what volume at 65° C.?

5. If 300 cc. of gas are measured off at 28° C., what will the volume become at −14° C.?

6. A liter of gas is heated from 14° C. to 42° C. Find the new volume.

7. A liter of air at 39° C. is cooled to −26° C. Find the new volume.

8. 50 cc. of gas at 10° C. occupy what volume at 24° C.?

9. 100 cc. of air at 12° C. are heated until they occupy 145 cc. Find the new temperature.

10. 320 cc. of gas are measured off at 91° C. and 950 mm.; what is the normal volume?

11. 542 cc. of air at 269° C. and 900 mm. are cooled to 51° C., the pressure being decreased to 666 mm. Find the new volume.

12. 546 cc. of gas at 17° C. and 760 mm. are cooled to 0° C., the pressure being decreased to 600 mm. Find the new volume.

13. A quantity of oxygen, which measures 230 liters at 14° C. and 740 mm., will measure what at 0° C. and 760 mm.?

14. 1234 cc. of normal gas are cooled to −52° C., the pressure being decreased to 617 mm. Find the new volume.

## MISCELLANEOUS EXAMPLES.

1. 50 grams of potassium chlorate are heated; what mass of oxygen is given off?

$$KClO_3 = KCl + 3\,O.$$

2. How much potassium chlorate is required to make 112 liters of oxygen?

$$KClO_3 = KCl + 3\,O.$$

3. What volume of oxygen can be obtained from 20 grams of manganese dioxide by heating it alone?

$$3\,MnO_2 = Mn_3O_4 + O_2.$$

4. What mass of oxygen can be obtained by heating 522 grams of manganese dioxide?

$$3\,MnO_2 = Mn_3O_4 + O_2.$$

5. What mass of oxygen ($O_2$) at 10° C. and 750 mm. would fill a globe of 15 liters capacity?

6. On heating some potassium chlorate 298 grains of potassium chloride were left. What mass of chlorate was heated, and what mass of oxygen was formed?

$$KClO_3 = KCl + 3\,O.$$

7. How much potassium chlorate is required to make 70 liters of oxygen?

8. 60 grams of mercuric oxide are heated; what volume of oxygen at 91° C. and 380 mm. is given off?

$$HgO = Hg + O.$$

9. 270 grams of mercuric oxide are heated; what volume

of oxygen at 0° C. and 760 mm. is given off? And what will the gas measure at 17° C. and 700 mm.?

$$HgO = Hg + O.$$

10. What is the mass of 13 liters of oxygen ($O_2$) measured at 12° C.?

11. 100 grams of steam are passed over red-hot iron. What volume of hydrogen at 10° C. and 742 mm. is formed?

$$4\,H_2O + 3\,Fe = Fe_3O_4 + 4\,H_2.$$

12. How many liters of hydrogen are obtained on dissolving 16 grams of magnesium in dilute sulphuric acid?

$$Mg + H_2SO_4 = MgSO_4 + H_2.$$

13. What volume will 1000 cc. of hydrogen at 0° C. occupy at (*a*) 15° C., (*b*) 100° C., (*c*) 300° C.?

14. What volume will 1000 cc. of hydrogen at 100° C. occupy, at (*a*) 0° C., (*b*) −20° C., (*c*) −50° C.?

15. 4 liters of hydrogen are passed over heated cupric oxide; what loss of mass does the oxide undergo?

$$H_2 + CuO = Cu + H_2O.$$

16. Find the percentage of hydrogen in (*a*) HCl, (*b*) $H_2S$, (*c*) $NH_4$.

17. How much zinc is required to obtain 100 liters of hydrogen at 91° C. and 800 mm.?

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

18. What volume of oxygen at 12° C. and 762 mm. is evolved on decomposing 10 grams of water by electricity?

$$H_2O = H_2 + O.$$

19. 500 cc. of hydrogen at 39° C. are exploded with 500 cc. of oxygen under a pressure of 332.5 mm.; what volume of which gas is left?

$$H_2 + O = H_2O.$$

20. 2 grams of steam are passed over red-hot iron; what volume of hydrogen at 10° C. and 770 mm. is formed?

$$4\,H_2O + 3\,Fe = Fe_3O_4 + 4\,H_2.$$

21. 100 grams of gypsum are heated; what volume of steam at 300° C. is given off?

$$CaSO_4,\ 2\,H_2O = CaSO_4 + 2\,H_2O.$$

22. 100 grams of each variety of sodium carbonate (*a*) $Na_2CO_3$, $10\,H_2O$; (*b*) $Na_2CO_3$, $8\,H_2O$; (*c*) $Na_2CO_3$, $5\,H_2O$; (*d*) $Na_2CO_3$, $H_2O$, contain how many grams of water?

23. What do 100 liters of nitrogen ($N_2$) weigh?

24. 146 liters of nitrogen at 17° C. and 974 mm. are heated to 51° C., the pressure being decreased to 760 mm. Find the new volume.

25. Find the percentage composition of ammonium nitrate $NH_4NO_3$.

26. How many pounds of nitric acid are obtained on distilling 400 pounds of sodium nitrate with sulphuric acid?

$$2\,NaNO_3 + H_2SO_4 = Na_2SO_4 + 2\,HNO_3.$$

27. How much copper is required to form 10 liters of nitric oxide?

$$3\,Cu + 8\,HNO_3 = 3\,CuN_2O_6 + 4\,H_2O + 2\,NO.$$

28. What is the mass of 270 cc. of nitrogen measured over water at 8° C. and 768 mm.?

29. What is the volume of 20 grams of ammonia ($NH_3$) at 12° C. and 730 mm.?

30. 25.82 liters of nitric oxide diffuse through a certain apparatus in 50 minutes; what volume of hydrogen will diffuse under same conditions?

31. The pressure on 134 cc. of air is increased from 480 mm. to 1200 mm. Find the new volume.

32. What volume of air containing 21 per cent of oxygen by volume is required to burn 248 grams of phosphorus?

$$P_2 + O_5 = P_2O_5.$$

33. How much phosphorus is required to remove the oxygen from a liter of air?

$$P_2 + O_5 = P_2O_5.$$

34. 10 liters of carbon monoxide at 14° C. and 760 mm. are required; what volume of normal carbon dioxide must be passed over red-hot carbon, and what mass of carbon is absorbed?

$$CO_2 + C = 2CO.$$

35. A substance contains carbon 20 per cent, oxygen 26.6 per cent, and sulphur 53.3 per cent. Find its formula.

36. A diamond weighing 7 grams is burnt in oxygen; what volume of carbon dioxide is formed?

$$C + O_2 = CO_2.$$

37. 10 grams of turpentine are burnt; what volume of carbon dioxide is formed?

$$C_{10}H_{16} + 28\,O = 8\,H_2O + 10\,CO_2.$$

38. How much marble must be dissolved in acid to give 20 liters of carbon dioxide at 18° C. and 740 mm.?

$$CaCO_3 + 2\,HCl = CaCl_2 + H_2O + CO_2.$$

39. How much hydrogen potassium carbonate is required to give a liter of carbon dioxide?

$$HKCO_3 + HCl = KCl + H_2O + CO_2.$$

40. What volume is occupied by 177.5 grams of chlorine ($Cl_2$)?

41. How much salt is required to make 28 liters of chlorine?

$$2\,NaCl + MnO_2 + 2\,H_2SO_4 = 2\,H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

42. 500 grams of potassium chlorate are heated; how much potassium chloride is left?

43. Find the percentage composition of bleaching powder, if its formula be $CaO_2Cl_2$.

44. From 2078 grams of sodium chloride what volume of chlorine can be obtained?

$$2\,NaCl + MnO_2 + 2\,H_2SO_4 = 2\,H_2O + Na_2SO_4 + MnSO_4 + Cl_2.$$

45. Find the percentage composition of (*a*) galena, PbS; (*b*) zinc blende, ZnS.

46. 9.6 grams of sulphur are heated in hydrogen; what volume of hydrogen sulphide is formed?

$$S + H_2 = H_2S.$$

47. 16 liters of hydrogen diffuse through an apparatus in 100 minutes; how much sulphur dioxide ($SO_2$) will diffuse under the same conditions?

48. What volume of sulphur dioxide at 20° C. and 740 mm. can be obtained by the action of 20 grams of sulphuric acid upon copper?

$$Cu + 2\,H_2SO_4 = CuSO_4 + 2\,H_2O + SO_2.$$

49. 100 grams of lead form 146.45 grams of lead sulphate; find the molecular weight of sulphuric acid.

$$Pb + H_2SO_4 = H_2 + PbSO_4.$$

50. The skeleton of a man weighs 24 lbs., and contains 58 per cent of calcium phosphate ($Ca_2 . 2PO_4$). Find the quantity of phosphorus present.

51. How much phosphorus can be obtained from 169 tons of bones containing 53.7 per cent of calcium phosphate ($Ca_3 . 2PO_4$)?

52. Find the percentage composition of crystallized hydrogen sodium phosphate ($Na_2HPO_4 . 12H_2O$).

53. How many grams do 10 liters of hydrogen phosphide weigh?

54. 10 liters of hydrogen diffuse through a certain apparatus in a certain time; what volume of hydrogen phosphide ($PH_3$) will diffuse under similar conditions?

55. In a case of poisoning, 11.73 grains of arsenic trisulphide were found; to how much arsenic trioxide does this correspond?

$$As_2S_3 + 9\,O = As_2O_3 + 3\,SO_2.$$

56. A room 15 feet long and 10 feet wide and high is covered with a paper containing .78 grains of Scheele's green ($CuHAs_5O_3$) per square foot. How much arsenic is there in the room?

57. To make a kilogram of potassium hydrate, how much (*a*) potassium carbonate and (*b*) calcium hydrate is required?

$$K_2CO_3 + CaH_2O_2 = CaCO_3 + 2\,KHO.$$

58. How much dry sodium carbonate can be made from 500 kilograms of common salt?

$$2\,NaCl + H_2SO_4 = 2\,HCl + Na_2SO_4.$$
$$Na_2SO_4 + CaCO_3 + 4\,C = 4\,CO + CaS + Na_2CO_3.$$

# PART II.

# ELEMENTARY QUALITATIVE ANALYSIS.

## SECTION I.

### PRELIMINARY EXAMINATION OF SINGLE SALTS CONTAINING ONE ACID AND ONE BASE.

### TABLE I. **Examination for Acid.***

**54.** If the substance is a solid, powder a portion of it, and heat in a glass tube sealed at one end. Notice whether water is given off. If so, test its action with litmus paper.

Acid reaction indicates *sulphites*, *chlorides*, etc.

Alkaline reaction indicates salts of *ammonium* ($NH_4$).

If a sublimate forms: yellow (or in red globules) indicates *sulphur;* white, *ammonium salts*, *mercury*, *arsenic*, *antimony.*

Metalic mirror indicates *arsenic.*

If a gas is evolved: oxygen indicates *chlorates*, *nitrates*, *peroxides;* carbon monoxide indicates *oxalates;* nitrogen tetroxide indicates *nitrates;* ammonia indicates *ammonium salts;* carbon dioxide indicates *carbonates.*

If the substance alters in color: black indicates *organic matter;* yellow while hot indicates *zinc oxide.*

---

* **Mercury, sulphur, ammonia, though not acids, are included.**

Take another portion of substance under analysis, and add HCl. Notice whether a gas is evolved with effervescence.

If it smell like burning sulphur, it indicates *sulphites*, or *hyposulphites.*

If it has the odor of rotten eggs, *sulphides.*

If it has the odor of bitter almonds, *cyanides.*

If it has the odor of chlorine on heating, *peroxides*, *chromates*, or *hypochlorites.*

If it renders lime-water turbid, *carbonates.*

Take another portion of substance, and try if it is soluble in water; if so, add $BaCl_2$ solution to a portion of the solution and notice whether a precipitate form.

A white precipitate insoluble in HCl indicates *sulphates.*

White and soluble in HCl indicates *phosphates*, *silicates*, *oxalates*, *borates*, and *fluorides*, also *carbonates* and *sulphites.*

Yellow indicates *chromates.*

If $BaCl_2$ gives no precipitate, add $AgNO_3$ to another portion of the solution and notice if a precipitate form.

White precipitate indicates *chlorides*, also *cyanides.*

Yellowish-white indicates *bromides* and *iodides.*

Black indicates *sulphides.*

In case neither water nor HCl has dissolved the substance, try $HNO_3$.

If this does not dissolve it, try aqua regia; and if that fails, try method described in Table II.

If the substance is dissolved in $HNO_3$ or aqua regia, it must be evaporated to dryness with HCl before proceeding to the examination for base.

## SECTION II.

### Examination for Base.

**55.** Having obtained a solution, add HCl. If it produces a precipitate, it indicates *silver*, *lead*, or *mercurous salts*. Add HCl + $H_2S$. If it produces a precipitate,

Black indicates *mercuric salts*, *lead*, *bismuth*, or *copper;*
Yellow indicates *arsenic*, *stannic salts*, or *cadmium;*
Orange indicates *antimony;*
Brown indicates *stannous salts.*

If $(NH_4)HO + (NH_4)Cl + (NH_4)_2S$ produce a precipitate, it indicates

Black, *iron*, *nickel*, *cobalt;*
White, *zinc* or *aluminum;*
Flesh-colored, *manganese;*
Green, *chromium.*

If $(NH_4)HO + (NH_4)Cl + (NH_4)_2CO_3$ produce a precipitate, it indicates

*Barium* (tinges flame green),
*Strontium* (tinges flame crimson),
*Calcium* (tinges flame dull red).

If the solution is not precipitated by any of the above reagents, it indicates *magnesium*, *potassium*, *sodium*, *ammonium*, of which the following are the individual tests: —

*Magnesium* is precipitated by $Na_2HPO_4 + (NH_4)HO$, white.

*Potassium* is precipitated (except in very dilute solutions) by $PtCl_4$, precipitate insoluble in alcohol; also tinges the flame violet.

*Sodium* is precipitated by $H_2SiF_6$; also tinges flame intense yellow, not visible through blue glass.

*Ammonium salts* heated with NaHO give smell of $NH_3$.

## TABLE II.

**Examination of Insoluble Substances.** The following substances are, under certain circumstances, insoluble in acids, and must be examined specially:—

*Silica*, *Silicates.*
*Alumina*, *Aluminates.*
*Oxides* of *Antimony*, *Chromium*, and *Tin.*
*Chrome Iron Ore.*
*Sulphates* of *Barium*, *Strontium*, and *Lead.*
Certain *Fluorides* (*e.g.* of *Calcium*).
Certain *Sulphides* (*e.g.* of *Lead*).
*Chloride*, *Bromide*, and *Iodide of Silver.*
*Carbon.*
*Sulphur.*

Heat the substance in a dry tube as before, and notice if it fuses and volatilizes completely. If it smells of $SO_2$, it indicates *sulphur.*

If it fuses, but does not volatilize, indicates *chloride*, *bromide*, or *iodide of silver* (also will yield metallic silver on fusing on charcoal with $Na_2CO_3$).

If it is infusible, but disappears on heating, *carbon* (deflagrates when heated with $KNO_3$).

If it is infusible, but darkened in color while hot, regaining its color on cooling, *tin dioxide and antimony pentoxide* (confirmed by blow-pipe test — tin bead malleable; antimony bead, brittle).

Notice whether. It yields a green bead with borax or microcosmic salt; it indicates *chromium oxide*, or *chrome iron ore*. It swims undissolved in a bead of microcosmic salt, *silica* and *silicates* (fuse with four times its weight of a mixture of $K_2CO_3$ and $Na_2CO_3$. Allow to cool, dissolve in water, add HCl, and evaporate to dryness. Silica will separate out as a gelatinous mass).

It yields a colorless bead, with microcosmic salt, *alumina*. (Heated on charcoal, and moistened with $CO(NO_3)_2$ and reheated, it yields a blue, infusible mass.)

It is white and infusible, but quite unaltered by heating.

*Lead sulphate* yields, when heated with $Na_2CO_3$ in blowpipe reducing flame, malleable metallic bead.

*Barium sulphate* fused with $Na_2CO_3$ yields $BaCO_3$. Boil the fused mass with water, filter and wash; the residue dissolved in HCl yields $BaCl_2$ (flame color green), precipitated by $SrSO_4$ solution.

*Strontium sulphate* fused with $Na_2CO_3$ yields $SrCO_3$. Boil the fused mass with water, filter and wash; the residue dissolved in HCl yields $SrCl_2$ (flame color crimson), precipitated by $CaSO_4$ solution.

*Calcium fluoride* heated with $H_2SO_4$ yields HF, which etches glass.

It is black and infusible, and yields a malleable metallic bead when fused with $Na_2CO_3$ in the blow-pipe flame.

*Lead sulphide* (bead leaves mark on paper), and when dissolved in $HNO_3$ gives a white precipitate on addition of $H_2SO_4$.

The action of strong $H_2SO_4$ often affords a valuable indication of the nature of a salt, whether soluble or insoluble.

Thus evolution of

Sulphur dioxide indicates *sulphites* or *hyposulphites.*

Sulphuretted hydrogen indicates *sulphides.*

Hydrocyanic acid indicates *cyanides.*

Oxygen indicates *peroxides*, *chromates*, *permanganates.*

Carbon dioxide indicates *carbonates.*

Carbon monoxide indicates *oxalates*, *formates*, *ferrocyanides.*

Chlorine indicates *hypochlorites.*

Hydrochloric acid indicates *chlorides.*

Hydrofluoric acid indicates *fluorides.*

Nitric acid indicates *nitrates.*

Acetic acid indicates *acetates.*

Chlorine tetroxide indicates *chlorates.*

## REACTIONS OF THE COMMONLY OCCURRING METALS WITH THE METHODS OF SEPARATION.

### GROUPING OF THE METALS.

**56.** The metals are divided into five groups, according to their behavior with certain substances termed *group reagents.*

### Group I. (*Silver Group.*)

Group reagent, HCl. Metals whose chlorides are insoluble in water. They are precipitated from the solutions of their salts by the first group reagent, *hydrochloric acid.*

*Silver*, *mercury* (mercurous salts), *lead.*

### **Group II.** (*Copper Group.*)

Group reagent $H_2S$ in presence of HCl. Metals which in acid solutions form insoluble sulphides, are precipitated from their acidulated solutions by the second group reagent $H_2S$ (hydrosulphuric acid).

*Arsenic*, *antimony*, *tin*, *lead*, *bismuth*, *copper*, *cadmium*, *mercury* (*mercuric salts*).

The three metals, *arsenic*, *antimony*, and *tin*, form a sub-group, as their sulphides are soluble in $(NH_4)_2S_2$, whilst the sulphides of the remaining metals are insoluble in that reagent.

### **Group III.** (*Iron Group.*)

Group reagent $(NH_4)_2S$ in presence of $(NH_4)Cl$ and $(NH_4)HO$.

Metals whose sulphides and hydroxides are insoluble in water, but decomposed by dilute acids, are precipitated from neutral solutions by the third group reagent, ammonium sulphide. *Aluminium*, and *chromium* are precipitated as hydrates; the others as sulphides. *Iron*, *nickel*, *cobalt*, *zinc*, *manganese*, as *sulphides*.

### **Group IV.** (*Barium Group.*)

Group reagent $(NH_4)_2CO_3$ in presence of $(NH_4)HO$ and $(NH_4)Cl$.

Metals whose carbonates are insoluble in water, and are precipitated from their solutions by the fourth group reagent, ammonium carbonate; *barium*, *strontium*, *calcium*.

### **Group V.** (*Potassium Group.*)

Metals not precipitated by any of the above group reagents, as their chlorides, sulphides and carbonates are soluble in water. They are, therefore, distinguished by individual tests: *magnesium*, *potassium*, *sodium*, *ammonium.*

**57.** Each group reagent will precipitate the metals of preceding groups. The metals distinguished by being insoluble as chlorides (Group I.) are also insoluble as sulphides (with Groups II. and III.) and as carbonates (with Group IV.). The second group sulphides are precipitated both from acid and from neutral solutions, though the third group sulphides are precipitated from neutral, but not from acid solutions, and second and third group metals form insoluble carbonates, as well as those of Group IV.

In the work of analysis, the first group metals may be worked with the second, but thereafter the metals found in each group must be completely removed before testing for the next group.

After filtering out a group precipitate, the reagent which produced it should be again carefully applied, with the proper conditions, to the filtrate before testing it for the next group.

The student should at first have several metallic salts given to him, and be asked merely to determine to which of the above groups each salt belongs.

He ought next to make himself familiar with the individual tests for each metal which follows, and then proceed to the separations of the different metals. It will also be well for him to attempt to frame a table of separations for each group before consulting those given in the book.

### 58. Reactions of the Metals of the Silver Group (Group I.).

*Silver*, Ag′, 108. *Solution for Reactions*, $AgNO_3$.

1. HCl produces a white, curdy precipitate of AgCl, insoluble in hot water, soluble in $NH_4HO$ and in KCN; reprecipitated by $HNO_3$; darkens on exposure to light.

2. $H_2S$ or $(NH_4)_2S$ produces a black precipitate of $Ag_2S$, soluble in boiling $HNO_3$, with separation of sulphur.

3. NaHO produces a light-brown precipitate of $Ag_2O$, soluble in $(NH_4)HO$.

4. $(NH_4)HO$ produces (from neutral solutions only) brown $Ag_2O$, soluble in excess of reagent.

5. $K_2CrO_4$ produces a dark-red precipitate of $Ag_2CrO_4$, soluble in hot $HNO_3$ or in $(NH_4)HO$; this solution deposits on cooling an acid chromate in needle-shaped crystals.

6. KI precipitates yellowish AgI.

7. Cu and some other metals precipitate metallic Ag.

8. $Na_2HPO_4$ precipitates yellow $Ag_3PO_4$.

9. Heated on charcoal with $Na_2CO_3$, in the reducing flame of the blow-pipe, yields bright, malleable metallic beads, soluble in $HNO_3$.

Characteristic reaction, 1.

*Mercury*, Hg″, 200 (*Mercurous Salts*). *Solution for Reactions*, $Hg_2N_2O_6$.

1. HCl produces white precipitate of $Hg_2Cl_2$ (calomel), insoluble in cold $HNO_3$; blackened by $(NH_4)HO$, from formation of $Hg_2Cl(NH_2)$.

2. $H_2S$ or $(NH_4)_2S$ produces a black precipitate of $Hg_2S$, not dissolved by boiling $HNO_3$.

3. NaHO precipitates black $Hg_2O$, insoluble in excess of NaHO or $(NH_4)HO$; decomposes readily into HgO and Hg.

4. $SnCl_2$ precipitates gray Hg. If the fluid be poured off and the residue boiled with HCl, distinct globules are obtained.

5. KI precipitates dark-green $Hg_2I_2$.

6. A drop of a metal or only slightly acid solution of a mercurous salt placed on a bright copper coin will deposit mercury, and the stain will become bright by rubbing.

7. Heated in small tube with $NaHCO_3$, yields gray deposit of Hg. Hg is volatile, and condenses on the cooler parts of the tube; soluble in $HNO_3$.

Characteristic reactions, 1, 7.

### *Lead*, Pb″, 207. *Solution for Reaction*, $PbN_2O_6$.

1. HCl precipitates (incompletely) white $PbCl_2$, soluble in boiling $H_2O$, or in large quantity of cold $H_2O$; converted into a basic salt on adding $(NH_4)HO$, without change of appearance. If $PbCl_2$ be dissolved in boiling $H_2O$, it will crystallize from this solution on cooling.

2. $H_2SO_4$ precipitates heavy white $PbSO_4$, soluble in NaHO or ammonium tartarate. This precipitate in dilute solutions only appears on standing. If there is no immediate precipitation, concentrate the solution by evaporation. $PbSO_4$ is soluble in boiling HCl, and the solution, on cooling, deposits needle-shaped crystals of $PbCl_2$.

3. $H_2S$ or $(NH_4)_2S$ precipitates black PbS, soluble in hot $HNO_3$.

4. $K_2CrO_4$ precipitates bright-yellow (chrome-yellow) $PbCrO_4$; soluble in NaHO; soluble with difficulty in $HNO_3$.

5. KI precipitates bright-yellow $PbI_2$, soluble in boiling $H_2O$; the solution on cooling deposits the salt in brilliant, golden hexagonal crystals.

6. Zn precipitates metallic Pb in crystalline form. Known as the "lead tree."

7. Heated on charcoal with $NaHCO_3$, yields malleable beads of Pb, soluble in $HNO_3$, and at the same time a yellow incrustation of PbO on the charcoal.

Characteristic reactions, 2, 4, 5.

### 59. **Table II. for the Separation of Silver** (Group I.).

*Silver*, *Mercury*, *and Lead.*

(*a*) Add HCl until no further precipitation takes place. Filter from the precipitated chlorides.

| Precipitate contains | Filtrate contains |
|---|---|
| AgCl, $Hg_2Cl_2$, $PbCl_2$. | Group II., III., IV., and V. |

(*b*) Wash precipitate twice with cold $H_2O$, and add washings to filtrate; then twice with hot $H_2O$. Test part of this for Pb with dilute $H_2SO_4$. White precipitate indicates *lead*. Boil remainder down to obtain crystals of $PbCl_2$. If Pb is found, the precipitate is washed repeatedly with hot $H_2O$, till free from it. Residue indicates AgCl, $Hg_2Cl_2$, insoluble in hot $H_2O$.

(*c*) To residue add warm $(NH_4)HO$; filter.

| Residue is Hg. | Filtrate Ag. |
|---|---|
| If residue is black, it indicates *mercury*. Dissolve in $HCl + HNO_3$, and test with $SnCl_2$. | Add $HNO_3$; white precipitate indicates the presence of *silver*. |

## Reactions of the Metals of the Copper Group.

**60.** Metals whose sulphides are insoluble in HCl and are precipitated in presence of that acid by the group reagent $H_2S$.

### MERCURY, LEAD, BISMUTH, COPPER, CADMIUM, ARSENIC, ANTIMONY, AND TIN.

Sub-Group A. Sulphides of the above metals insoluble in $(NH_4)_2S_2$, viz.: *Mercury*, *Lead*, *Copper*, *Bismuth*, and *Cadmium*.

*Mercury*, $Hg''$ (*Mercuric Salts*). *Solution for Reactions*, $HgCl_2$.

1. $H_2S$ produces, when added by degrees, first a white precipitate, which changes to orange, then to brownish-red, and finally to a black precipitate of HgS. These successive changes of color on the addition of $H_2S$ are exceedingly characteristic. This precipitate is insoluble in HCl and in $HNO_3$, even on boiling; it is soluble in KHS and in aqua regia.
2. KHO produces a yellow precipitate of HgO insoluble in excess, except when added to very acid solutions.
3. $(NH_4)HO$ produces a white precipitate of $HgCl(NH_2)$ (white precipitate).
4. $SnCl_2$ when added in small quantities precipitates white $Hg_2Cl_2$; when added in excess, gray metallic Hg, which may be united into a globule by boiling with HCl.
5. KI precipitates bright-red $HgI_2$, soluble in excess of either KI or $HgCl_2$.
6. $K_2CrO_4$ precipitates an orange basic chromate easily soluble in $HNO_3$.

7. Reactions 6 and 7 for mercurous salts are also produced with mercuric.

Characteristic reactions, 1, 4.

*Lead*, Pb'', 207. *Solution for Reactions*, $PbN_2O_6$.

1. $H_2S$ precipitates black PbS, even in solutions of $PbCl_2$, so that lead belongs to both the silver and the copper groups.
2. Reactions 2, 3, 4, 5, for lead in Group I. are also applicable in this group.

*Bismuth*, Bi''', 210. *Solution for Reactions*, $BiCl_3$.

1. $H_2S$ precipitates black $Bi_2S_3$, insoluble in KHS and KHO, but soluble in $HNO_3$.
2. KHO or $(NH_4)HO$ precipitates white BiO.OH, which on boiling becomes yellow ($Bi_2O_3$); precipitate is insoluble in excess of either reagent.
3. $H_2O$, when added in considerable quantity to normal salts of bismuth, precipitates white basic salt of bismuth, BiOCl, insoluble in tartaric acid. Solutions of bismuth salts containing much free acid do not give this reaction with $H_2O$ until the excess of acid has been expelled by evaporation.
4. Zn or Fe precipitates spongy Bi.
5. $K_2CrO_4$ precipitates yellow $Bi_2.3(CrO_4)$, soluble in $HNO_3$, and insoluble in NaHO.
6. Heated on charcoal with $NaHCO_3$, in reducing flame of blow-pipe, compounds of Bi yield brittle metallic globules; also a yellow incrustation of $Bi_2O_3$ on the charcoal. Bi is soluble in $HNO_3$ or aqua regia.

Characteristic reactions, 3, 6.

### *Copper*, Cu'', 63.5. *Solution for Reactions*, $CuSO_4$.

1. $H_2S$ precipitates black, CuS, soluble in $HNO_3$; insoluble in KHS, and only slightly soluble in $(NH_4)_2S_2$. CuS is also soluble in KCN, but insoluble in hot dilute $H_2SO_4$.

2. KHO precipitates a pale-blue $Cu(HO)_2$, insoluble in excess. If KHO be added in excess and the mixture boiled, the precipitate becomes black.

3. $(NH_4)HO$ precipitates, when added in small quantities, greenish-blue basic salt, soluble in excess of $(NH_4)HO$, forming a dark-blue solution which consists of double basic salt of copper and ammonium.

4. $K_4Fe(CN)_6$ precipitates brown $Cu_2Fe(CN)_6$, insoluble in dilute acids, but decomposed by KHO.

5. Fe precipitates Cu in the metallic state, especially in the presence of a little free acid.

6. Zn also precipitates copper solutions.

7. $K_2CrO_4$ precipitates a brownish-red basic chromate, soluble in $HNO_3$ and in $(NH_4)HO$.

8. Compounds of Cu, when heated in Bunsen flame, impart a green color, especially after addition of AgCl.

9. Heated on charcoal with $NaHCO_3$ in reducing flame, yields brittle metallic globules of bright-red color, soluble in $HNO_3$ or concentrated $H_2SO_4$.

Characteristic reactions, 3, 5, 6.

### *Cadmium*, Cd'', 112. *Solution for Reactions*, $CdN_2O_6$.

1. $H_2S$ precipitates yellow CdS, soluble in $HNO_3$, insoluble in KHS, KCN, and $(NH_4)_2S$. CdS is dissolved by hot dilute $H_2SO_4$.

2. KHO precipitates $Cd(HO)_2$, insoluble in excess of reagent.

3. $(NH_4)HO$ precipitates $Cd(HO)_2$; soluble in excess of reagent.

4. Zn precipitates Cd in brilliant scales.

5. Heated on charcoal with $NaHCO_3$ in the reducing flame, yields a brown incrustation of CdO. Cd dissolves readily in $HNO_3$.

Characteristic reactions, 1, 5.

## TABLE III.

### 61. Copper Group (II.).

*Separation of Mercury, Lead, Bismuth, Copper, and Cadmium* (*Sub-Group A*).

To the filtrate from the Silver Group add an equal bulk of HCl, boil down nearly to dryness, dilute with $H_2O$, and pass $H_2S$ through the hot solution. Filter.

| RESIDUE. | FILTRATE. |
|---|---|
| **HgS, PbS, $Bi_2S_3$, CuS, CdS, SnS, $SnS_2$, $Sb_2S_3$, and $As_2S_3$.** | Groups III., IV., and V. |

**Wash with hot $H_2O$ containing $H_2S$, until free from Cl; digest residue* with $(NH_4)_2S_2$ for about fifteen minutes. Filter.**

| RESIDUE. | FILTRATE. |
|---|---|
| **HgS, PbS, $Bi_2S_3$, CuS, and CdS.** | Sub-Group B.<br>(Sn, Sb, and As.)<br>(See Table IV.) |

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*** In the absence of the sub-group omit this, and treat with $HNO_3$ as below.**

Wash with hot $H_2O$ till no longer alkaline; add a small quantity of boiling $HNO_3$, pouring it on several times. Filter.

RESIDUE.

**HgS.**

Dissolve in aqua regia, boil down to expel acid, and test with $SnCl_2$. White precipitate changing to gray indicates **Mercury**. Confirm by reduction test, or Bunsen's test for mercury.

FILTRATE.

**Pb, Bi, Cu, Cd.**

Add $H_2SO_4$, and boil down. White precipitate indicates **Lead**. Filter from $PbSO_4$, and add $(NH_4)HO$ to filtrate. Filter.

RESIDUE.

**Bi.**

A white precipitate. Dissolve in HCl, evaporate to a small bulk, and add to $H_2O$. A white precipitate indicates **Bismuth.**

FILTRATE.

**Cu, Cd.**

A blue solution indicates **Copper.** Adopt Method I. or II.

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METHOD I.

Add to the blue solution KCN till colorless; pass a few bubbles of $H_2S$ through the solution. Yellow precipitate indicates **Cadmium**. (Excess of $H_2S$ must be avoided, because traces of mercury may be present.)

METHOD II.

Add HCl till acid; pass $H_2S$ through; filter; wash rapidly and thoroughly, and treat with hot dilute $H_2SO_4$. Black residue indicates **Copper**. To filtrate, add $H_2S$. Yellow precipitate indicates **Cadmium.**

**62.** Sub-Group B. Sulphides soluble in $(NH_4)_2S_2$, viz.: those of *Tin*, *Antimony*, and *Arsenic*.

*Tin*, Sn″, 118 (*Stannous Salts*). *Solution for Reactions*, $SnCl_2$.

1. $H_2S$ precipitates dark-brown SnS, soluble in yellow $(NH_4)_2S_2$ (nearly insoluble in colorless $(NH_4)_2S$); reprecipitated as yellow $SnS_2$ by HCl.

2. KHO precipitates $Sn(HO)_2$, soluble in excess of reagent.

3. $(NH_4)HO$ precipitates $Sn(HO)_2$, not soluble in excess.

4. $HgCl_2$ precipitates at first white $Hg_2Cl_2$; on boiling with excess of reagent, gray Hg.

5. $AuCl_3$, on addition of a little $HNO_3$, precipitates purple (royal purple of Cassius).

6. Zn precipitates metallic tin.

7. Mixed with $NaHCO_3+KCN$, and heated on charcoal in reducing flame, yields small globules of Sn and a white incrustation of $SnO_2$.

*Stannic Salts*, $Sn^{iv}$. *Solution for Reactions*, $SnCl_4$.

Stannous salts are converted into stannic by oxidizing agents, $HNO_3$, Cl, $Fe_2Cl_6$, etc.

1. $H_2S$ precipitates yellow $SnS_2$, soluble in $(NH_4)_2S$, in KHO, and in boiling concentrated HCl. It is with difficulty soluble in $(NH_4)HO$, and insoluble in $(NH_4)_2CO_3$.

2. KHO or $(NH_4)HO$ precipitates white $SNO(HO)_2$, soluble in an excess of precipitant.

3. Zn produces same reaction as with stannous salts.

4. The blow-pipe reaction for stannic is the same as for stannous.

Characteristic reaction: stannous, 1, 4; stannic, 1.

**63.** *Antimony*, Sb''', 122.3. *Solution for Reactions*, $SbCl_3$.

1. $H_2S$ precipitates orange $Sb_2S_3$, soluble in $(NH_4)_2S$, NaHO, and in hot concentrated HCl; insoluble in $(NH_4)_2CO_3$.

2. KHO precipitates $Sb_2O_3$, soluble in excess of reagent.

3. $(NH_4)HO$ precipitates $Sb_2O_3$, insoluble in excess.

4. $H_2O$ produces in solutions of $SbCl_3$ a white precipitate of SbOCl, soluble in tartaric acid.

5. Zn in presence of HCl and platinum precipitates Sb as a black powder, which adheres to the platinum. The black stain on the platinum is not removed by HCl, but is immediately dissolved by warm $HNO_3$.

6. (Marsh's Test.) If a solution of Sb be placed in a flask in which hydrogen is being generated, $SbH_3$ is given off as a gas, which is decomposed by heat, Sb being deposited. This is best done by holding in the $SbH_3$ flame a piece of cold porcelain; a dull-black stain of metallic Sb will be deposited on it. Add to the stain on the porcelain a drop of NaClO; the stain will remain undissolved.

7. Heated with $NaHCO_3$ on charcoal in the reducing blow-pipe flame, yields brittle globules of the metal and a white incrustation of $Sb_2O_3$ on the charcoal.

Characteristic reactions, 5, 6.

**64.** *Arsenic*, As''' (*Arsenious Compounds*). *Solution for Reactions*, $Na_3AsO_3$.

1. $H_2S$ (in acid solutions) precipitates yellow $As_2S_3$, soluble in alkaline sulphides in KHO, in $HNO_3$, and in $(NH_4)_2CO_3$, but nearly insoluble in boiling concentrated HCl.

2. $(NH_4)HO$ and NaHO produce no precipitates.

3. $AgNO_3$ produces in neutral solutions a pale-yellow precipitate of $Ag_3AsO_3$.

4. $CuSO_4$ added to a neutral solution precipitates $CuHAsO_3$ (Scheel's green), soluble in $(NH_4)HO$.

5. Cu added to an HCl solution of arsenic becomes coated with a gray film of metallic As. *Reinsch's test.*

6. Proceed exactly as in Marsh's test for Sb, substituting a solution of As for one of Sb, and observe the bluish flame with which the mixture of H and $AsH_3$ burns, and also the production of white fumes, $As_2O_3$. Obtain stains on cold porcelain as in the case of Sb. Observe the distinction in color of the stains. Dark-brown or almost black, in the case of Sb; pale-brown and lustrous in the case of As. Add to one of the stains on porcelain a drop of NaClO; it will be rapidly dissolved.

7. Arsenious compounds are converted into arsenic compounds by oxidizing agents.

*Arsenic Compounds*, $As^{v}$. *Solution for Reactions*, $Na_3AsO_4$.

1. $H_2S$ in warm solutions free from $HNO_3$ precipitates $As_2S_3$ and S.

2. See 2, under Arsenious Compounds.

3. $AgNO_3$ precipitates from neutral solutions reddish-brown $Ag_3AsO_4$.

4. $MgSO_4$ in presence of $(NH_4)HO$ and $(NH_4)Cl$ precipitates white crystalline $MgNH_4AsO_4$.

5. Heated on charcoal with $Na_2CO_3$, all compounds of arsenic are reduced to As, which volatilizes with characteristic garlic odor.

6. See 6, under Arsenious Compounds, Marsh's test.

Characteristic tests: arsenious, 4, 5, 6; arsenic, 5, 6.

## TABLE IV.

## Group II.

**65.** *Separation of Arsenic, Antimony, and Tin (Sub-Group B).*

Solution in $(NH_4)_2S_2$ contains sulphides of As, Sb, and Sn. Add HCl until acid: the metals are re-precipitated as sulphides. Filter; wash precipitate with hot water till free from HCl; digest precipitate with one or two pieces of solid $(NH_4)_2CO_3$ and $H_2O$. Filter.

| RESIDUE. | FILTRATE. |
|---|---|
| $SnS_2$, $Sb_2S_3$. | As. |
| Wash and dissolve in strong boiling HCl, dilute with water, and add to the solution a piece of zinc and platinum: Sb forms a black stain on the platinum. Dissolve in $HNO_3$, boil down to a small bulk, and pass $H_2S$ through the solution: orange precipitate indicates presence of **Antimony.** The Sn deposits on the zinc; dissolve in HCl, boil down, and test with $HgCl_2$. White precipitate indicates **Tin.** | Add HCl until acid; wash precipitated sulphide, and dissolve in HCl and a little $KClO_3$, boil down to a small bulk, and apply Marsh's test. Metallic mirror, yielding octahedral crystals on heating, indicates **Arsenic.** Dissolve in $H_2O$, and confirm by adding $AgNO_3$ and dilute $(NH_4)HO$, to obtain yellow precipitate of $Ag_3AsO_3$. |

## 66. Reactions of the Metals of the Iron Group (Group III.).

Metals whose sulphides and hydrated oxides are insoluble in water, and are precipitated on addition of the group reagent $(NH_4)_2S$ in presence of $(NH_4)HO$ and $(NH_4)Cl$.

### IRON, NICKEL, COBALT, ZINC, ALUMINUM, MANGANESE, AND CHROMIUM.

*Iron*, Fe'', 56 (*Ferrous Salts*). *Solution for Reactions*, $FeCl_2$.

1. $(NH_4)_2S$ precipitates black FeS, soluble in HCl, insoluble in alkalies.

2. $(NH_4)HO$ or KHO precipitates white $Fe(HO)_2$, which rapidly acquires a dirty-green color, and ultimately a reddish-brown color, owing to absorption of oxygen and conversion into ferric hydrate $Fe_2(HO)_6$.

3. $(NH_4)_2CO_3$ or $Na_2CO_3$ precipitates white $FeCO_3$, which rapidly darkens in color.

4. $K_4Fe(CN)_6$ precipitates white $K_2Fe_2(CN)_6$, which rapidly becomes blue by oxidization to $Fe_5(CN)_{12}$ (Prussian blue).

5. $K_3Fe(CN)_6$ precipitates "Turnbull's blue," $Fe_3Fe_2(CN)_{12}$.

6. KCNS produces no coloration.

7. $BaCO_3$ produces no precipitate in cold solution of ferrous salts.

8. Ferrous compounds are converted into ferric by oxidizing agents, such as $HNO_3$, $KClO_3$, HCl, Cl.

9. Fused with borax in the oxidizing flame, yellowish-red beads are produced; in the reducing flame the beads become green.

### *Ferric Salts*, $Fe^{iv}$. *Solution*, $Fe_2Cl_6$.

1. $H_2S$ in acid solutions produces a precipitate of sulphur, and the salt is reduced to protosalt:—

$$Fe_2Cl_6 + H_2S = 2\,FeCl_2 + 2\,HCl + S.$$

2. $(NH_4)_2S$ precipitates black FeS and S, soluble in HCl and $HNO_3$.

3. $(NH_4)HO$ or KHO precipitates reddish-brown $Fe_2(HO)_6$, insoluble in excess of reagent.

4. $K_4Fe(CN)_6$ precipitates "Prussian blue," $Fe_5(CN)_{12}$, insoluble in HCl, soluble in $C_2H_2O_4$.

5. $K_3Fe(CN)_6$ produces a reddish-brown color.

6. KCNS produces, even in dilute solutions, an intense blood-red color, forming a soluble iron sulphocyanide. HCl does not destroy coloration, but it is destroyed by $C_2H_3O_2Na$, $HgCl_2$, $H_3PO_4$, and $C_4H_6O_6$.

7. $BaCO_3$ precipitates ferric solutions completely as $Fe_2(HO)_6$ mixed with basic salt.

8. The blow-pipe reactions are the same as for ferrous compounds.

9. Heated on charcoal with $Na_2CO_3$, compounds of Fe yield magnetic particles, but no globules.

Characteristic reactions: ferrous salts, 5; ferric, 4, 6.

### 67. *Nickel*, $Ni''^{, iv}$, 58.7. *Solution*, $NiN_2O_6$.

1. $(NH_4)_2S$ precipitates black NiS, slightly soluble in excess, forming a brown solution, from which NiS is precipitated on boiling, insoluble in HCl, soluble in $HNO_3$ and aqua regia.

2. (Na)HO or KHO precipitates light-green $Ni(HO)_2$, insoluble in excess of the reagent.

3. $(NH_4)HO$ produces a precipitate of $Ni(HO)_2$, readily soluble in excess, yielding a blue fluid. Acid solutions, or those containing salts of ammonia, yield no precipitate with $(NH_4)HO$.

4. KCN precipitates yellowish-green $Ni(CN)_2$, soluble in excess and reprecipitated by HCl or $H_2SO_4$, and if boiled with a strong solution of NaClO, yields a black precipitate of $Ni_2(HO)_6$.

5. $KNO_3$ in presence of $C_2H_4O_2$ produces no precipitate.

6. Fused with borax compounds of Ni, yields reddish-yellow beads when hot in oxidizing flame. In reducing flame the bead becomes gray.

Characteristic reactions, 2, 3.

### **68.** *Cobalt*, $Co^{'', iv}$, 58.7. *Solution*, $CoN_2O_6$.

1. $(NH_4)_2S$ precipitates black CoS, insoluble in excess of reagent and in HCl, soluble in aqua regia.

2. KHO or NaHO precipitates blue basic salts, which turn green on exposure to air by oxidation.

3. $(NH_4)HO$ precipitates the same as above, soluble in excess, yielding a reddish-brown fluid; reprecipitated by NaHO or KHO. Acid solutions, or those containing salts of ammonia, are not precipitated.

4. KCN precipitates light-brown $Co(CN)_2$, soluble in excess of the reagent by formation of $2KCN, Co(CN)_2$. This solution is reprecipitated by addition of HCl or $H_2SO_4$. If to the solution in excess of KCN a few drops of HCl be added, and the solution boiled for some time, $K_3Co(CN)_6$, potassium cobaltic cyanide, is formed, which is not reprecipitated by HCl or $H_2SO_4$, nor by NaClO.

5. $KNO_2$ added to cobalt solutions with addition of acetic acid precipitate, on standing, a yellow crystalline double salt.

6. Compounds of cobalt fused with borax in either blow-pipe flame yield deep-blue beads.

### **69.** *Zinc*, $Zn''$, 65.2. *Solution*, $ZnSO_4$.

1. $(NH_4)_2S$ precipitates white ZnS, insoluble in excess of reagent and in KHO; soluble in the mineral acids.

2. KHO or NaHO precipitates white $Zn(HO)_2$, soluble in excess of either reagent and in $(NH_4)HO$; reprecipitated from dilute solutions by boiling, but not by $NH_4Cl$.

3. $Na_2CO_3$ precipitates white basic carbonate, insoluble in excess of reagent.

4. $(NH_4)_2CO_3$ precipitates also the basic carbonate, but it is soluble in excess of the reagent.

5. Heated on charcoal with $Na_2CO_3$ in the reducing blow-pipe flame, a yellow incrustation of ZnO is obtained, which becomes white when cold.

6. Heated on charcoal by the blow-pipe flame, after moistening with $CoCl_2$ solution, an infusible green mass is obtained.

Characteristic reaction, 1.

### 70. *Aluminium*, $Al^{iv}$, 27.3. *Solution*, $Al_2.3SO_4$.

1. $(NH_4)_2S$ precipitates white $Al_2(HO)_6$, soluble in acids.

2. KHO or NaHO produces also a precipitate of $Al_2(HO)_6$, soluble in acids, even in hot acetic acid, and in excess of the reagent. This solution is not precipitated by $H_2S$, but is reprecipitated by $NH_4Cl$, or by adding $(NH_4)HO$ after acidifying with HCl.

3. $(NH_4)HO$ also precipitates $Al_2(HO)_6$, soluble in a very large excess of the reagent, more difficultly soluble in presence of salts of ammonia.

4. $BaCO_3$ produces a precipitate of $Al_2(HO)_6$ mixed with basic salt.

5. $Na_2HPO_4$ precipitates aluminium phosphate, insoluble in $(NH_4)HO$ and in $NH_4Cl$, but soluble in KHO or NaHO, and in acids. It does not, however, dissolve in hot acetic acid like aluminium hydrate.

6. Heated on charcoal in the blow-pipe flame, then moistened with $CoCl_2$, and reheated, an infusible blue mass is obtained.

Characteristic reactions, 2, 6.

### 71. *Manganese*, $Mn^{ii, iv}$, 55. *Solution*, $MnSO_4$.

1. $(NH_4)_2S$ produces a flesh-colored precipitate of MnS, soluble in acids, even in acetic acid.

2. KHO or NaHO produces a dirty-white precipitate of $Mn(HO)_2$, insoluble in excess of the reagent; the precipitate rapidly darkens in color by absorption of oxygen. The freshly-precipitated hydrate is dissolved by $NH_4Cl$, but the higher oxide is insoluble.

3. $(NH_4)HO$ produces the same precipitate of $Mn(HO)_2$, insoluble in excess of the reagent; but it gives no precipitate if the manganese solution contain $NH_4Cl$. Such a solution on standing precipitates the dark-brown hydrate.

4. $Na_2CO_3$ produces a white precipitate of $MnCO_3$, which darkens in color by absorption of oxygen.

5. If any manganese solution (free from chlorine) be treated with $PbO_2$ and then boiled with $HNO_3$, it is converted into permanganate, which is recognized by its pink color as soon as the mixture has settled.

6. If any manganese compound be fused on platinum foil with $Na_2CO_3$ and a trace of $KNO_3$, it is converted into $Na_2MnO_4$, recognized by its bright-green color.

7. Fused with borax in the oxidizing flame, an amethyst-colored bead is obtained, which becomes colorless in the reducing flame.

Characteristic reactions, 1, 6, 7.

### **72.** *Chromium*, $Cr^{iv}$, 52.1. *Solution*, $Cr_2 . 3SO_4$.

1. $(NH_4)_2S$ produces a bluish-green precipitate of $Cr_2(HO)_6$, insoluble in excess of the reagent, soluble in acids.

2. $(NH_4)HO$ also precipitates the hydrate, soluble to some extent in excess, yielding a pink fluid, but on heating, the precipitation is complete.

3. KHO or NaHO precipitates also $Cr_2(HO)_6$, soluble

however in excess, yielding a green or bluish-violet solution. On continued boiling or addition of $NH_4Cl$ and heating, the hydrate is reprecipitated.

4. $BaCO_3$ produces a precipitate of $Cr_2(HO)_6$ along with basic salt; the precipitation is not complete till the mixture has stood some time.

5. Fused with $Na_2CO_3$ and $KNO_3$ on platinum foil, yellow $Na_2CrO_4$ is obtained.

6. Fused with borax in either flame (but best in the reducing flame), green beads are obtained.

**Characteristic reactions, color of solutions and bead.**

TABLE

## 73. Iron Group (III.). *Separation of Iron, Nickel,*

To filtrate from the sulphides of the Cu and As groups add $(NH_4)HO$ (till shake for some time. Filter. Wash well with $H_2O$, containing $(NH_4)_2S$, dilute HCl,

**Residue.**

**NiS and CoS.**

Test for Co by borax bead. Dissolve the black residue in HCl and $KClO_3$. Boil down just to dryness, dilute with $H_2O$, add KCN in excess, then a drop of acetic acid, boil for a few minutes, add NaClO in excess, and boil again. A black precipitate indicates **Nickel.** The filtrate from this precipitate may be tested for Co by evaporating to dryness, and fusing in a borax bead. Blue color indicates **Cobalt.**

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**Method I.** Cr is absent.

Boil down with a little $KClO_3$ till it smells of Cl. Add pure NaHO till strongly alkaline. Filter.

**Residue.**

**$Fe_2(HO)_6$, $Mn(HO)_2$.**

Wash with hot $H_2O$, dissolve in HCl, add $(NH_4)HO$, and filter.

**Residue.**

**$Fe_2(HO)_6$.**

Dissolve in HCl. Test with $K_4Fe(CN)_6$. Blue precipitate indicates **Iron.** To ascertain whether the iron is present as ferrous or ferric salt, the *original solution* must be tested with $K_4Fe(CN)_6$, and $K_3Fe(CN)_6$.

**Filtrate.**

**Mn.**

Boil down and ignite, to expel salts of ammonium. Fuse with NaHO and $KNO_3$. A green residue indicates **Manganese.** Traces of Ni and Co are found along with the Mn.

**Filtrate.**

**Al, Zn.**

Divide into two parts.

1. Add $H_2S$ or $(NH_4)_2S$. A white precipitate indicates **Zinc.** Confirm by flame reaction.

2. Add HCl till acid, then $(NH_4)HO$ till alkaline. A white precipitate indicates **Aluminium.** Confirm by flame reaction.

### V.

*Cobalt, Aluminium, Zinc, Manganese, and Chromium.*

alkaline) + $NH_4Cl$ + $(NH_4)_2S$. Warm the mixture gently in a small flask and and finally once with $H_2O$ alone. Treat the precipitate with cold and filter.

**Filtrate.**

**Cr, Al, Fe, Zn, and Mn.**

(Green or violet if Cr be present. Boil down a portion, and test for Cr by borax bead. Adopt Method I. if absent, Method II. if present.)

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**Method II. Cr is present.**

Boil down with a little $KClO_3$ till it smells of Cl. Add $Na_2CO_3$ or NaHO till just neutral or slightly acid; allow to become *perfectly* cold. Add excess of $BaCO_3$, place in a flask, cork up and shake well, allow to stand till clear. Filter.

**Residue.**

**$Fe_2(HO)_6$, $Cr_2(HO)_6$, $Al_2(HO)_6$ (also excess of $BaCO_3$).**

Wash well, boil with pure NaHO, and filter; add HCl to the filtrate, and then $(NH_4)HO$ till alkaline. A white precipitate indicates **Aluminium.** Confirm by flame reaction. Fuse the residue insoluble in NaHO with a mixture of $Na_2CO_3$ and $KNO_3$; extract with water, and filter.

**Residue.**

**$Fe_2(HO)_6$.**

Dissolve in HCl, and test with $K_4Fe(CN)_6$. A blue precipitate indicates **Iron.**

**Filtrate.**

**Cr.**

Yellow in color. Acidify with acetic acid; add lead acetate. A bright-yellow precipitate indicates **Chromium.**

**Filtrate.**

**Zn, Mn.**

Precipitate the Ba present with $H_2SO_4$ in the hot solution. Boil well, and filter; add NaHO. Precipitate indicates **Manganese.** Confirm by fusing with $Na_2CO_3$ and $KNO_3$ on platinum foil. To the filtrate from the $Mn(HO)_2$ add $(NH_4)_2S$. A white precipitate indicates **Zinc.** Confirm by flame reaction.

## Reactions of the Metals of the Barium Group (Group IV.).

**74.** Metals whose carbonates are insoluble in water, and whose solutions are precipitated on the addition of $(NH_4)_2CO_3$. As, however, the carbonates are soluble in acids, the solution, if acid, must be neutralized by addition of $(NH_4)HO$.

### BARIUM, STRONTIUM, CALCIUM.

*Barium*, Ba'', 137. *Solution*, $BaCl_2$.

1. $(NH_4)_2CO_3$ precipitates white $BaCO_3$, soluble in acids, and to a slight extent in $NH_4Cl$.

2. $K_2CO_3$ or $Na_2CO_3$ precipitates also $BaCO_3$, insoluble in excess of either reagent.

3. $H_2SO_4$ or any soluble sulphate, even in dilute solutions, precipitates heavy white $BaSO_4$, insoluble in acids, alkalies, or salts of ammonium.

4. $CaSO_4$ or $SrSO_4$ precipitates immediately white $BaSO_4$.

5. $H_2SiF_6$ precipitates white $BaSiF_6$.

6. $C_2(NH_4)_2O_4$ precipitates white $C_2BaO_4$, soluble in HCl and in $HNO_3$.

7. $K_2CrO_4$ precipitates yellow $BaCrO_4$, insoluble in $C_2H_4O_2$, but soluble in HCl and $HNO_3$.

8. Heated in the lamp flame, a green coloration is produced, especially on moistening the salt with HCl.

Characteristic reactions, 3, 8.

**75.** *Strontium*, Sr'', 87.5. *Solution*, $SrCl_2$.

1. $(NH_4)_2CO_3$ or $K_2CO_3$ precipitates white $SrCO_3$, soluble in acids, but less soluble in $NH_4Cl$ than $BaCO_3$.

2. $H_2SO_4$ precipitates white $SrSO_4$, much less insoluble in $H_2O$ than $BaSO_4$; it therefore precipitates from dilute solutions only on standing or warming. $SrSO_4$ is slightly soluble in HCl.

3. $CaSO_4$, after standing some time, precipitates white $SrSO_4$.

4. $H_2SiF_6$ does not precipitate strontium solutions.

5. $C_2(NH_4)_2O_4$ precipitates white $C_2SrO_4$, soluble in HCl and in $HNO_3$, also to a slight extent in $NH_4Cl$, but very sparingly in $C_2H_4O_2$.

6. $K_2CrO_4$, only in concentrated solutions, precipitates yellow $SrCrO_4$, soluble in $C_2H_4O_2$.

7. Heated in the lamp flame, a crimson coloration is produced, especially on moistening the salt with HCl.

Characteristic reactions, 3, 7.

### **76.** *Calcium*, Ca'', 40. *Solution*, $CaCl_2$.

1. $(NH_4)_2CO_3$ or $K_2CO_3$ precipitates white $CaCO_3$, which becomes crystalline on heating.

2. $H_2SO_4$ precipitates from strong solutions of calcium salts $CaSO_4$ as a white precipitate, which dissolves in a large excess of water, and also in acids.

3. $CaSO_4$ produces no precipitate.

4. $H_2SiF_6$ produces no precipitate.

5. $C_2(NH_4)_2O_4$, even in dilute solutions, precipitates white $C_2CaO_4$, soluble in HCl or $HNO_3$, but insoluble in $C_2H_2O_4$ or in $C_2H_4O_2$.

6. Heated in the lamp flame, a dull-red coloration is produced, especially on moistening the salt with HCl. This reaction is imperceptible in presence of Ba or Sr salts.

Characteristic reactions, 5, 6.

## TABLE VI.

### 77. **Barium Group (IV.).** *Separation of Barium, Strontium, and Calcium.*

Heat filtrate from iron group, add to the hot solution $NH_4Cl$ and $(NH_4)_2CO_3$, and filter. Wash precipitate with hot $H_2O$, dissolve in HCl, and add $CaSO_4$ solution. An immediate precipitate indicates **Barium**; a precipitate after some time indicates **Strontium**, or a dilute Barium solution. (Test another portion with $SrSO_4$ for Ba.) To another portion of the solution in HCl add $H_2SO_4$, and boil to remove Ba and Sr. Filter. Neutralize filtrate with $(NH_4)HO$, and add $C_2(NH_4)_2O_4$. An immediate precipitate indicates **Calcium**.

### TO TEST FOR STRONTIUM.

#### I. Ba present; Ca absent.

Dissolve the carbonate in HCl, and evaporate to dryness. Treat the residue with strong alcohol. Filter.

| Residue. | Filtrate. |
|---|---|
| $BaCl_2$. | Sr. |
| Confirm by flame test. Green coloration indicates **Barium**. | Confirm by lighting the alcoholic solution. Crimson coloration indicates **Strontium**. |

#### II. Ba absent; Ca present.

Dissolve as before, and precipitate with $H_2SO_4$. Filter, and wash well.

| Residue. | Filtrate. |
|---|---|
| $SrSO_4$. | Ca. |
| If small, burn the filter in the reducing gas flame to convert $SrSO_4$ into SrS; moisten with HCl, and test in the lamp flame. Crimson coloration indicates **Strontium**. | Neutralize the solution with $(NH_4)HO$, and test with $C_2(NH_4)_2O_4$. White precipitate indicates **Calcium**. |

### Another Method.

Dissolve in $HNO_3$, and evaporate to dryness. Treat with strong alcohol. Filter.

| Residue. | Filtrate. |
|---|---|
| $Sr(NO_3)_2$. | Ca. |
| Confirm as above. | Confirm as above. |

### III. Ba and Ca present.

Add $H_2SO_4$ to the HCl solution (diluted to prevent precipitation of Calcium), and filter.

| Residue. | Filtrate. |
|---|---|
| $BaSO_4$, $SrSO_4$. | Ca. |
| Boil in a beaker with a little water, together with a mixture of three parts $K_2SO_4$ and one part $K_2CO_3$. Filter, and treat residue with $HNO_3$. The $SrSO_4$ is dissolved, and the $BaSO_4$ left undissolved. (Traces of Ca may be found with the Sr.) | Neutralize the solution with $(NH_4)HO$, and test with $C_2(NH_4)_2O_4$. White precipitate indicates Calcium. |

### Another Method.

Dissolve the carbonates in $C_2H_4O_2$, and precipitate the Ba with $K_2CrO_4$. Filter. Precipitate the Sr and Ca by $(NH_4)_2CO_3$, and proceed as in Method II. (Ba absent, Ca present).

## Reactions of the Metals of the Potassium Group (Group V.).

**78.** Metals whose solutions are unprecipitated by the preceding group reagents, and having no common precipitant. They are therefore recognized by individual tests.

### MAGNESIUM, POTASSIUM, AMMONIUM, SODIUM.

*Magnesium*, $Mg''$, 24. *Solution*, $MgSO_4$.

1. $(NH_4)HO$ and $(NH_4)_2CO_3$ give no precipitates in the presence of salts of ammonium.

2. $Na_2HPO_4$ in presence of $(NH_4)HO$ and $(NH_4)Cl$ a crystalline white precipitate of $MgNH_4PO_4$. The precipitation is slow from dilute solutions, but may be hastened by stirring with a glass rod and warming. Precipitate soluble in dilute mineral acids and in $C_2H_4O_2$, almost insoluble in dilute solution of $(NH_4)HO$.

3. $H_2SO_4$, $H_2SiF_6$, and $C_2(NH_4)_2O_4$ give no precipitates.

4. Heated on charcoal in the blow-pipe flame, and then moistened with $CoCl_2$ or $CoN_2O_6$ and reheated, gives a pink mass.

Characteristic reactions, 2, 4.

**79.** *Potassium*, $K'$, 39.1. *Solution*, $KCl$.

1. $PtCl_4$, except in dilute solutions, gives a crystalline yellow precipitate of $2KCl + PtCl_4$. The precipitation is hastened by stirring or the addition of alcohol.

2. $H_2Tr$ or $NaHTr$ precipitates white crystalline $KHTr$ from concentrated solutions.

3. $H_2SiF_6$ precipitates white gelatinous $K_2SiF_6$.

4. Heated on platinum wire, potassium compounds color the flame violet, appearing reddish-violet through blue glass.

Characteristic reaction, 4.

### **80.** *Ammonium*, $NH_4$, 18. *Solution*, $NH_4Cl$.

1. $PtCl_4$ gives a crystalline yellow precipitate of $2NH_4Cl + PtCl_4$, except in dilute solutions. Precipitate insoluble in alcohol and ether. On ignition, precipitate leaves a residue of spongy platinum.

2. NaHTr or $H_2Tr$ give in strong solutions a white precipitate of $(NH_4)HTr$.

3. $H_2SiF_6$ gives no precipitate.

4. Nessler's solution gives a brown precipitate, or in any dilute solutions a yellow coloration.

5. Heated with NaHO or KHO, compounds of ammonium evolve ammonia gas, recognized by its odor, alkaline reaction, and fuming with HCl.

6. Heated on platinum foil, all compounds of ammonia volatilize completely.

Characteristic reactions, 4, 5, 6.

### **81.** *Sodium*, $Na'$, 23. *Solution*, NaCl.

1. $PtCl_4$, NaHTr, and $H_2Tr$ give no precipitates.

2. $H_2SiF_6$ gives precipitate of white gelatinous $Na_2SiF_6$.

3. The salts of sodium being almost without an exception soluble in water, the flame test alone serves to distinguish the metal. Heated on platinum foil or wire in non-luminous flame, an intense yellow color is produced, not seen when viewed through blue glass.

## TABLE VII.

### 82. **Group V.** *Separation of Magnesium, Potassium, Sodium, and Ammonium.*

The filtrate from the Barium group is concentrated by evaporation, and a portion ignited on platinum foil. If no residue is left on ignition, Mg, K, and Na are absent.

| **Detection of $NH_4$.** | **Detection of Mg.** | **Detection of K and Na.**<br>(1.) Mg being absent. | **Detection of K and Na.**<br>(2.) Mg being present. |
|---|---|---|---|
| The original substance or solution is heated with NaHO in a test-tube. Presence of **Ammonium** shown by smell, by the white fumes with HCl, and by its action on red litmus paper. | To a portion of the concentrated cold solution add $(NH_4)HO$ and $Na_2HPO_4$. White crystalline precipitate denotes **Magnesium.** | Evaporate another portion of the solution to dryness, ignite residue, dissolve in a small quantity of water, filter if required, and add to the clear liquid $PtCl_4$, evaporate nearly to dryness, and add alcohol. Yellow precipitate indicates **Potassium.** | Evaporate the solution to dryness, ignite residue, dissolve in water, and add baryta water until the solution has an alkaline reaction; boil; filter. To filtrate, add $(NH_4)_2CO_3$, heat, filter, evaporate to dryness, and test the residue for **K** and **Na.** |

**To detect Na.**

Evaporate alcoholic solution (which must have a yellow color, showing that excess of $PtCl_4$ has been added) nearly to dryness, add a grain or two of sugar, and ignite residue. Exhaust with water, filter, evaporate to dryness; and if a residue be left, test it by flame reaction for Na. Yellow coloration indicates **Sodium.**

## PRECIPITATIONS IN THE FIVE GROUPS OF BASES.

| *Precipitated by* | GROUP I. | GROUP II. | GROUP III. | GROUP IV. | GROUP V. |
|---|---|---|---|---|---|
| I. Chlorides . . . | Pb,† Ag, $Hg_2$. | | | | |
| II. $H_2S$ in Acid Sol. . . . . | Pb, Ag, $Hg_2$. | As, Sb, Sn, Bi, Cu, Cd, Hg. | | | |
| III. Sulphides . . . | Pb, Ag, $Hg_2$. | As,* Sb,* Sn,* Bi, Cu, Cd, Hg. | Zn, Al, Fe, Mn, Cr, Co, Ni. | | |
| IV. Carbonates with $(NH_4)Cl$ | Pb, Ag, $Hg_2$. | Sb,* Sn, Bi, Cu, Cd, Hg. | Zn, Al, Fe, Mn, Cr, Co, Ni. | Ba, Sr, Ca. | |
| Carbonates . . . . . | Pb, Ag, $Hg_2$. | Sb,* Sn, Bi, Cu, Cd, Hg. | Zn, Al, Fe, Mn, Cr, Co, Ni. | Ba, Sr, Ca. | Mg. |
| Fixed Alkalies . . . | Pb,* Ag, $Hg_2$. | Sb,* Sn,* Bi, Cu, Cd, Hg. | Zn,* Al,* Fe, Mn, Cr,* Co, Ni. | Ba,† Sr,† Ca. | Mg. |
| Ammonia . . . . . . | Pb, Ag,* $Hg_2$. | Sb, Sn, Bi, Cu,* Cd,* Hg. | Zn,* Al, Fe, Mn, Cr, Co,* Ni.* | | Mg. |
| Phosphates . . . . . | Pb, Ag, $Hg_2$. | Sb, Sn, Bi, Cu, Cd, Hg. | Zn, Al, Fe, Mn, Cr, Co, Ni. | Ba, Sr, Ca. | Mg. |
| Oxalates . . . . . . | Pb, Ag, $Hg_2$. | Sb, Sn, Bi, Cu, Cd, Hg. | Zn, Al, Fe, Mn, Co, Ni. | Ba,† Sr, Ca. | Mg.† |
| Sulphates . . . . . . | Pb. | | | Ba, Sr, Ca.† | |
| Sulphites . . . . . . | Pb, Ag, $Hg_2$. | Sb, Sn, Bi, Cu, Cd, Hg. | Zn, Al, Fe, Mn, Co, Ni. | Ba, Sr, Ca. | Mg. |
| Bromides . . . . . . | Pb, Ag, $Hg_2$. | | | | |
| Iodides . . . . . . . | Pb,* Ag,* Hg. | (Bi), Hg.* | | | |

* Soluble in excess of reagent. † Not precipitated in dilute solutions.

## REACTIONS OF THE ACIDS.

**83. Grouping of the Acids.** The acids can be approximately classified by means of certain group reagents.

They are divided into two great classes: *inorganic* and *organic acids*. These are easily distinguished by the action of heat.

Salts of *inorganic acids*, when heated to redness, are not charred; salts of *organic acids* are at once charred, owing to decomposition and separation of carbon (with the exception of acetic and formic acids).

### 84. Grouping of the Inorganic Acids.

#### Group I. (*Sulphuric Acid Group.*)

Group reagent, $BaCl_2$ in presence of HCl.

Sulphuric acid, hydrofluo-silicic acid.

The acids of this group are precipitated by $BaCl_2$, and the precipitate is not dissolved on addition of HCl.

#### Group II. (*Phosphoric Acid Group.*)

Group reagent, $BaCl_2$.

Phosphoric, boric, hydrofluoric, carbonic, silicic, sulphurous, arsenious, arsenic, iodic, chromic acids.

The acids of this group are precipitated in *neutral solutions* by $BaCl_2$.

#### Group III. (*Hydrochloric Acid Group.*)

Group reagent, $AgNO_3$.

Hydrochloric, hydrobromic, hydroiodic, hydrocyanic, and hydrosulphuric acids.

The acids of this group are precipitated by $AgNO_3$, and not by $BaCl_2$.

### **Group IV.** (*Nitric Acid Group.*)

Nitric, chloric, and perchloric acids.

These acids are not precipitated by any reagent, as all their salts are soluble in water.

## Reactions of the Inorganic Acids belonging to Group I.

**85.** Acids precipitated by $BaCl_2$ in presence of HCl.

SULPHURIC ACID, HYDROFLUO-SILICIC ACID.

### *Sulphuric Acid*, $H_2SO_4$, 98.

1. $BaCl_2$ precipitates a white $BaSO_4$, insoluble in HCl or $HNO_3$. In very dilute solutions the precipitation is not immediate, but on standing, the solution becomes clouded, and ultimately the precipitate subsides.

2. $Pb(NO_3)_2$ precipitates a heavy white $PbSO_4$, soluble in NaHO, and in boiling HCl (on allowing this solution to cool, $PbCl_2$ crystallizes out).

3. Fused on charcoal with $Na_2CO_3$ in the reducing flame of the blow-pipe, a sulphide is produced. If the fused mass be moistened with HCl, the odor of $H_2S$ is at once perceptible; or if it be placed on a bright piece of silver and moistened with water, a black stain of $Ag_2S$ is produced.

### **86.** *Hydrofluo-silicic Acid*, $H_2SiF_6$, 144.

1. $BaCl_2$ precipitates a crystalline $BaSiF_6$, insoluble in HCl.

2. KCl precipitates a gelatinous $K_2SiF_6$.

3. Heated with $H_2SO_4$ in a leaden crucible covered with

a piece of glass, the latter will be etched by the evolved HF.

### Reactions of the Acids belonging to Group II.

**87.** Acids precipitated by $BaCl_2$ in neutral solutions.

PHOSPHORIC, BORIC, HYDROFLUORIC, CARBONIC, SILICIC, SULPHUROUS, ARSENIOUS, ARSENIC, IODIC, AND CHROMIC ACIDS.

### *Phosphoric Acid*, $H_3PO_4$, 98.

1. $BaCl_2$ precipitates a white $BaHPO_4$, readily soluble in $HNO_3$ or HCl, but with difficulty in $NH_4Cl$.

2. $Mg_2SO_4$, along with $(NH_4)HO$ and $NH_4Cl$, precipitates a white crystalline $Mg(NH_4)PO_4+6H_2O$, insoluble in $(NH_4)HO$, but soluble in HCl, $HNO_3$, and acetic acid. In dilute solutions the precipitation does not take place till after the lapse of some time, but is promoted by stirring and gentle warming.

3. $AgNO_3$ precipitates a yellow $Ag_3PO_4$, soluble in $HNO_3$, and also in $(NH_4)HO$.

4. Lead acetate precipitates a white $Pb_3(PO_4)_2$, soluble in $HNO_3$, but almost insoluble in acetic acid.

5. $Fe_2Cl_6$, in presence of excess of sodium acetate, precipitates a yellowish $FePO_4$, soluble in HCl, and in excess of $Fe_2Cl_6$, which must be added drop by drop.

6. Ammonium molybdate produces in solutions acidified by $HNO_3$ a yellow color, and then a precipitate; this reaction is hastened by warming.

### **88.** *Boric Acid*, $B(HO)_3$, 62.

1. $BaCl_2$ precipitates a white $Ba(BO_2)_2$, soluble in acids.

2. $AgNO_3$ produces in strong solutions a yellowish-white precipitate. In dilute solutions $Ag_2O$ is precipitated.

3. $H_2SO_4$ or HCl, added to hot concentrated solutions of alkaline borates, on cooling, precipitates a crystalline $B(HO)_3$.

4. If alcohol containing free boric acid be kindled, it burns with a green flame, best seen on stirring the mixture. Borates may be examined in this way by first adding strong $H_2SO_4$, to liberate the $B(HO)_3$.

5. If the solution of a borate be made distinctly acid with HCl, and turmeric paper dipped into it, the latter, on gentle warming, acquires a brown tint, which is turned blue by caustic soda.

### **89.** *Hydrofluoric Acid*, HF, 20.

1. $BaCl_2$ precipitates a white $BaF_2$, soluble in HCl, and sparingly in $NH_4Cl$.

2. $CaCl_2$ produces a gelatinous and almost transparent precipitate of $CaF_2$, made more apparent on addition of $(NH_4)HO$. The precipitate is very difficultly soluble in HCl, even on boiling, and is nearly insoluble in acetic acid.

3. Heated with $H_2SO_4$, all fluorides are decomposed with evolution of HF, which is recognized by its power of etching glass.

4. Heated with a mixture of borax and $HKSO_4$, on a loop of platinum wire in the non-luminous flame, $BF_3$ is produced, coloring the flame green.

### **90.** *Carbonic Acid*, $H_2CO_3$, $H_2O + CO_2$.

1. $BaCl_2$ in neutral solutions precipitates a white $BaCO_3$, soluble in acids with effervescence.

2. Treated with dilute HCl, all carbonates at once evolve $CO_2$ with effervescence, which turns lime-water a milky white from the formation of $CaCO_3$.

### 91. *Silicic Acid*, $Si(HO)_4$, 96.

1. $BaCl_2$ precipitates a white $SiBa_2O_4$, which is decomposed on addition of HCl, and $Si(HO)_4$ separates out as a gelatinous precipitate.

2. HCl, added drop by drop to a strong solution of a silicate, precipitates a gelatinous $Si(HO)_4$; but if added to a dilute solution or in large excess, no precipitate is obtained until the mixture has been evaporated to dryness and ignited, when $SiO_2$ separates out, and this is not redissolved on addition of HCl.

3. Fused with $Na_2CO_3$ in a loop of platinum wire in the non-luminous gas-flame, effervescence occurs from the disengagement of $CO_2$, and the bead is transparent on cooling, unless the $Na_2CO_3$ be in excess.

4. Fused with microcosmic salt on a loop of platinum wire in the non-luminous gas-flame, solution does not take place, but the silica floats about on the bead undissolved.

### 92. *Sulphurous Acid*, $H_2SO_3$, 82.

1. $BaCl_2$ precipitates a white $BaSO_3$, soluble in HCl. On addition of chlorine water, gives a white precipitate of $BaSO_4$, the sulphite being oxidized to the sulphate.

2. $AgNO_3$ gives a white precipitate of $AgSO_3$, darkened on heating.

3. Added to a mixture of Zn and HCl, $H_2S$ is produced, and recognized by its smell and by its action on paper moistened with a solution of a lead salt, blackening it.

4. $H_2S$ decomposes pure $H_2SO_3$, with separation of sulphur.

5. $H_2SO_3$ is decomposed by HCl, with evolution of $SO_2$.

### **93.** *Arsenious Acid*, $H_3AsO_3$, 126.

1. $AgNO_3$ gives in neutral solutions a yellow precipitate of $Ag_3AsO_3$, soluble in $(NH_4)HO$.

2. $MgSO_4 + (NH_4)Cl + (NH_4)HO$ give no precipitate.

3. $H_2S$ precipitates $As_2S_3$, yellow.

### **94.** *Arsenic Acid*, $H_3AsO_4$, 142.

1. $AgNO_3$ gives in neutral solutions a light-brown precipitate of $AgAsO_4$.

2. $MgSO_4 + (NH_4)Cl + (NH_4)HO$ give a white precipitate of $MgNH_4AsO_4$.

3. $H_2S$ precipitates $As_2S_3$, yellow.

### **95.** *Iodic Acid*, $HIO_3$, 176.

1. $BaCl_2$ gives a white precipitate of $BaI_2O_6$, soluble in $HNO_3$.

2. $AgNO_3$ precipitates white crystalline $AgIO_3$, easily soluble in $(NH_4)HO$, but sparingly so in $HNO_3$.

3. $SO_2$ gives at first a precipitate of I, which is converted into HI on addition of excess of reagent.

4. $HIO_3$ is decomposed by $H_2S$, with formation of an iodide and separation of S.

5. Iodate salts, on heating, are decomposed, oxygen being evolved. In some cases iodine is given off in violet vapors.

### **96.** *Chromic Acid*, $H_2CrO_4$, 118.2.

1. $BaCl_2$ precipitates a yellow $BaCrO_4$, soluble in HCl and $HNO_3$, but insoluble in acetic acid.

2. $H_2S$ in presence of HCl reduces the solution to $Cr_2Cl_6$ (green), with separation of S. In neutral solutions, $Cr_2(HO)$ is precipitated along with S.

3. $SO_2$ reduces solutions of chromates to the chromic salt, the color of which is green. Chromates are likewise reduced by zinc and a dilute acid, by oxalic acid and dilute sulphuric acid, by strong $H_2SO_4$, by strong HCl, and by boiling the solution, acidified with HCl or $H_2SO_4$, along with alcohol.

4. $AgNO_3$ precipitates a dark-red $Ag_2CrO_4$, soluble in $HNO_3$ and in $(NH_4)HO$.

5. Lead acetate produces a bright-yellow precipitate of $PbCrO_4$, soluble in NaHO, but soluble with difficulty in dilute $HNO_3$.

6. $H_2CrO_4$ is precipitated by $(NH_4)_2S$ as $Cr_2(HO)_6$.

## Reactions of the Acids belonging to Group III.

**97.** Acids precipitated by $AgNO_3$, and not by $BaCl_2$.

### HYDROCHLORIC, HYDROBROMIC, HYDRIODIC, HYDROCYANIC, AND HYDROSULPHURIC ACIDS.

### *Hydrochloric Acid*, HCl, 36.5.

1. $AgNO_3$ precipitates a white curdy AgCl, which becomes violet on exposure to light. The precipitate is insoluble in $HNO_3$, but soluble in $(NH_4)HO$, in KCN, in $Na_2S_2O_3$, and also to some extent in NaCl.

2. Heated with $H_2SO_4$ and $MnO_2$, chlorides yield chlorine gas, recognized by its smell, bleaching action, and green color.

3. *Dry* chlorides, when heated in a retort with $H_2SO_4$ and $K_2Cr_2O_7$, yield $CrO_2Cl_2$ (chromium oxychloride),

which distils over into the receiver as a dark-red liquid, decomposed by addition of water or $(NH_4)HO$, yielding a yellow solution, which, on addition of a lead salt, gives a yellow precipitate of $PbCrO_4$.

### **98.** *Hydrobromic Acid*, HBr, 81.

1. $AgNO_3$ precipitates a pale-yellow AgBr, insoluble in dilute $HNO_3$, soluble in strong $(NH_4)HO$, and readily in KCN and $Na_2S_2O_3$.

2. Heated with $H_2SO_4$ and $MnO_2$, bromides yield red vapors of Br, recognized by its powerful odor.

3. Heated in a retort with $K_2Cr_2O_7$ and $H_2SO_4$, dry bromides yield dark-red vapors, which condense in the receiver to a liquid of the same color, which consists of pure bromine, and is decolorized on adding excess of $(NH_4)HO$.

### **99.** *Hydriodic Acid*, HI, 128.

1. $AgNO_3$ precipitates a pale-yellow AgI, insoluble in dilute $HNO_3$, and very difficultly soluble in $(NH_4)HO$, but readily in KCN and $Na_2S_2O_3$.

2. Cuprous sulphate precipitates a dirty-white $Cu_2I_2$, which separates most completely if the solution be made slightly alkaline with $Na_2CO_3$.

3. $KNO_2$ produces no reaction in solutions of iodides until a few drops of HCl or $H_2SO_4$ are added, when iodine is at once liberated and colors the solution yellow. If a little starch solution be now added, a deep-blue coloration results from the formation of starch iodide.

4. Chlorine water (or the gas) liberates iodine from iodides, but *excess* of Cl causes the formation of $ICl_3$,

which is colorless, and gives no blue coloration with starch solution.

5. Heated with $MnO_2$ and dilute $H_2SO_4$, violet vapors of iodine are obtained, which color starch paper blue.

### 100. *Hydrocyanic Acid*, $HCN$, 27.

1. $AgNO_3$ precipitates a white $AgCN$, insoluble in $HNO_3$, with difficulty in $(NH_4)HO$, but readily in $KCN$ and $Na_2S_2O_3$. $AgCN$ is decomposed on ignition, and metallic Ag remains; this serves to distinguish it from $AgCl$, which is not decomposed on ignition.

2. If a solution of $FeSO_4$ which has become oxidized by exposure to the air, be added to the solution of a cyanide made alkaline with $NaHO$, a bluish-green precipitate is formed, which is a mixture of Prussian blue with the hydrated oxides of iron. On adding $HCl$, these last are dissolved, and the blue precipitate remains.

3. $HCl$ decomposes nearly all cyanides with evolution of $HCN$, recognized by its odor, resembling bitter almonds.

4. $Hg(CN)_2$ cannot be detected by the above methods. The dry substance is detected by igniting in a small tube, when cyanogen gas is evolved, or the solution is decomposed by $H_2S$ and filtered from the $HgS$: the filtrate contains $HCN$.

### 101. *Hydrosulphuric Acid (Sulphuretted Hydrogen)*, $H_2S$, 34.

1. $AgNO_3$ precipitates a black $Ag_2S$, insoluble in dilute acids.

2. Lead acetate, even when highly dilute, precipitates black $PbS$,

3. Sodium nitro-prusside, in presence of NaHO, produces a reddish-violet coloration, even in very dilute solutions. The color disappears in a short time.

4. HCl or $H_2SO_4$ decomposes most sulphides with evolution of $H_2S$, recognized by its disagreeable odor and by its blackening paper moistened with solution of lead.

## Reactions of the Acids of Group IV.

**102.** Acids not precipitated by any reagent.

### *Nitric Acid*, $HNO_3$, 63.

1. Nitrates when heated evolve oxygen, and in some cases nitrous vapors also. On fusing a nitrate and adding a fragment of charcoal, vivid deflagration occurs.

2. Free $HNO_3$ heated with Cu gives red fumes; boiled with pieces of silk or wool turns them yellow.

3. If to a solution of a nitrate $FeSO_4$ and concentrated $H_2SO_4$ be poured carefully into the test-tube, a dark ring will appear on top of the $H_2SO_4$, which will be violet, red, or dark-brown according to the quantity of $HNO_3$ present. The ring disappears on warming.

### **103.** *Chloric Acid*, $HClO_3$, 84.5.

1. $H_2SO_4$ decomposes chlorates with evolution of $Cl_2O_4$, a greenish-yellow gas having a powerful odor. If heated, violent explosions occur; the mixture ought therefore to be kept cold, and only *very* small quantities should be used.

2. When chlorates are heated, oxygen is evolved, and a metallic chloride remains, which may be dissolved in water, and precipitated as AgCl by $AgNO_3$.

3. Chlorates are reduced by $SO_2$ with liberation of chlorine or its oxides; hence if the solution of a chlorate be colored blue with indigo solution, it is decolorized on adding $H_2SO_4$ and solution of $Na_2SO_3$. (Distinction from perchlorates.)

4. HCl decomposes chlorates with evolution of Cl and $Cl_2O_4$, a mixture called *euchlorine*.

5. Heated with charcoal, chlorates deflagrate violently.

### **104.** *Perchloric Acid*, $HClO_4$, 100.5.

1. $H_2SO_4$ does not act upon perchlorates in the cold, and on heating, white fumes of $HClO_4$ are given off, but no explosions occur.

2. KCl in strong solutions precipitates a white $KClO_4$.

3. Indigo solution is not decolorized when added to perchlorates warmed with HCl, as euchlorine is not evolved.

4. Dry perchlorates evolve oxygen on heating.

5. Perchlorates are not reduced by $SO_2$.

## TABLE VIII.

### *Detection of Inorganic Acids in Mixtures.*

(The following acids are found in examination for bases, which ought *always* to *precede* examination for acids:—

$H_2SO_3$,
$H_2S_2O_3$,
$H_2CO_3$,
$H_2S$.
$Si(HO)_4$,
$H_2CrO_4$,
$H_3AsO_3$,
$H_3AsO_4$.)

## I.

### *Acids in Soluble Bodies.*

1. Neutralize a portion of the solution with $(NH_4)HO$, and add $BaCl_2$ (or $Ba(NO_3)_2$ if Ag, $Hg_2$, or Pb be present): precipitate indicates $H_2SO_4$, $H_3PO_4$, $H_3AsO_3$, $H_3AsO_4$, $Si(HO)_4$, $H_2CrO_4$, and large quantities of $B(HO)_3$ and HF.*

To precipitate, add $H_2O$, and then HCl: if a precipitate remain, $H_2SO_4$ was present.

2. To another portion of the neutralized solution add $AgNO_3$: a precipitate indicates one or more of these acids; *i.e.*,

(*a*) HCl, HBr, HI, HCn, $H_4Fe(Cn)_6$, $H_3Fe(Cn)_6$, $H_2S$.

(*b*) $H_3PO_4$, $H_3AsO_4$, $H_3AsO_3$, $H_2CrO_4$, $Si(HO)_4$, $B(HO)_3$.*

To the precipitate add cold dilute $HNO_3$. Acids under (*a*) are insoluble; those under (*b*), soluble.

### *Detection of Acids under (a).*

To a portion of the solution add starch paste and one drop of a solution of $N_2O_3$ in $H_2SO_4$. Blue coloration indicates HI. Add chlorine water till the blue color disappears, and shake with chloroform. Reddish brown color indicates the presence of HBr. HCl is detected in presence of the others by boiling down the solution to dryness and distilling residue with $K_2Cr_2O_7$ and $H_2SO_4$ (see 97, 3).

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* Oxalic, citric, and tartaric acids will also be shown, if present.

### *Detection of Acids under (b).*

Test separately for each acid by the methods already given.

### *Separation of* $H_3AsO_3$, $H_3AsO_4$, *and* $H_3PO_4$.

Acidify solution with HCl, add $Na_2SO_3$, and heat until no smell of $SO_2$ is given off.

Pass $H_2S$ through the hot solution, filter, and test for $H_3PO_4$ with ammonium molybdate: yellow precipitate indicates $H_3PO_4$.

Precipitate another portion with magnesia mixture, and test both precipitate and filtrate for arsenic.

Test for the other acids by the following reactions, given under each acid: —

For HCn, by test 3, 100.
For $H_2S$, by test 4, 101.
For $HNO_3$, by tests 2 and 2, 102.
For $HClO_3$, by tests 1 and 2, 103.
For $B(HO)_3$, by tests 4 and 5, 88.
For $Si(HO)_4$, by tests 2 and 4, 96.
For $H_2SO_3$, by test 3, 92, and smell of $SO_2$ on adding HCl.
For $CO_2$, by test 2, 90.

# A SHORTER SYSTEM OF QUALITATIVE ANALYSIS.

## TESTS FOR BASES.

### *A.*

Add dilute HCl.

1. No prpt; pass to *B*.
2. A prpt; filter, filtrate to *B*; prpt may be

Ag, $Hg_2$, Pb.

Wash prpt twice with cold water, once with hot water; save only hot washing.

1. To hot washing add dilute $H_2SO_4$; prpt shows Pb.
2. To prpt on filter add $NH_4HO$.
   - *a*. Prpt turns black; $Hg_2$ present.
   - *b*. To ammoniacal filtrate add $HNO_3$ in excess; prpt shows Ag.

### *B.*

Add $H_2S$ water.

1. No prpt; pass to *C*.
2. A prpt. Saturate with $H_2S$ gas and filter; filtrate to *C*. Prpt may be

Cu, Bi, Cd, Pb; Hg; As, Sb, Sn.

Wash prpt carefully, warm with $(NH_4)_2S$, and filter.

1. Prpt. Boil with $HNO_3$, and filter.
   - *a*. Black residue shows Hg.

*b.* Solution. Add dilute $H_2SO_4$; white prpt shows Pb. Filter, and add $NH_4HO$; white prpt shows Bi, blue solution shows Cu; filter, and to filtrate add $H_2S$.
  *aa.* Yellow prpt shows Cd.
  *bb.* Brown prpt shows Cu; filter, dissolve prpt in KCy solution; yellow residue shows Cd.

2. Filtrate. Add dilute HCl.
  *a.* Pure white prpt; no As, Sb, Sn.
  *b.* Colored prpt; boil with $KClO_3$ crystals, put in evolution flask with dilute $H_2SO_4$ and Zn, tube dipping in $AgNO_3$ solution.
    *aa.* In $AgNO_3$ solution a black prpt shows Sb. Filter, to filtrate add more $AgNO_3$ solution, and then, carefully, very dilute $NH_4HO$; yellow prpt shows As.
    *bb.* In evolution flask remove Zn, add HCl, and warm, then add $HgCl_2$; white prpt shows Sn.

### *C.*

Add $NH_4Cl$, $NH_4HO$, and $(NH_4)_2S$.

1. No prpt; go on to *D*.

2. A prpt. Filter, filtrate to *D*. Prpt may be
Ni, Co; Fe, Al, Cr; Mn, Zn.

Treat prpt with cold $H_2O$ and HCl, and filter.

1. Black residue. Test with borax bead; brown shows Ni, blue shows Co or Co and Ni. In latter case dissolve residue in aqua regia, evaporate excess of acid, add $NaC_2H_3O_2$ and $KNO_3$ and let stand. Yellow prpt after a while shows Co. Filter, to filtrate add KHO; green prpt shows Ni.

2. Filtrate. Boil with $KClO_3$ crystals, nearly neutralize with $Na_2CO_3$, and let cool; then add $BaCO_3$ and let stand a while, shaking occasionally; then filter.
   - *a.* Prpt. Dissolve in dilute $H_2SO_4$, boil and filter; if necessary, boil filtrate and refilter; to filtrate add KHO in excess, boil three minutes and filter.
     - *aa.* Prpt. Fuse part on Pt with $KNO_3$ and $Na_2CO_3$, dissolve in $H_2O$, filter, add $C_2H_4O_2$; to filtrate add $Pb(C_2H_3O_2)_2$; yellow prpt shows Cr. Dissolve part in HCl and add KCfy; blue prpt shows Fe.
     - *bb.* Filtrate. Add HCl and $NH_4HO$; white prpt shows Al.
   - *b.* Filtrate. Add KHO in excess and filter.
     - *aa.* Filtrate. Add $H_2S$; white prpt shows Zn.
     - *bb.* Prpt. Fuse on Pt foil with $KNO_3$ and $Na_2CO_3$; green shows Mn.

### *D.*

Add $(NH_4)_2CO_3$.

1. No prpt; pass to *E.*
2. A prpt; filter, filtrate to *E.* Prpt may be

Ba, Sr, Ca.

Dissolve prpt on filter in $C_2H_4O_2$; to filtrate add $K_2Cr_2O_7$; yellow prpt shows Ba. Filter, to filtrate add $K_2SO_4$; prpt shows Sr. Filter, to filtrate add $(NH_4)_2C_2O_4$; prpt shows Ca. If no prpt, add dilute $H_2SO_4$ and alcohol; prpt shows Ca.

### *E.*

1. To some add $HNa_2PO_4$; prpt shows Mg.

2. Evaporate rest to dryness, and ignite gently. Residue may be K, Na.

Dissolve in very little dilute HCl.

Examine on Pt wire in flame; purple flame shows K; yellow, Na, or Na and K. In latter case add $PtCl_4$; yellow prpt shows K.

## *F.*

Boil some of original solution with KHO; $NH_4$ shown by its smell.

## TESTS FOR ACIDS.

Each acid must be tested for in a fresh portion of the original solution.

Add $BaCl_2$*; white prpt, insoluble in $HNO_3$, shows $H_2SO_4$.

Add $AgNO_3$.

1. White prpt, soluble in $NH_4HO$ and reprecipitated by $HNO_3$, shows HCl.
2. Yellowish prpt, insoluble in $NH_4HO$, shows HI.

HCl may also be present. Filter, to filtrate add $HNO_3$; prpt shows HCl.

Add strong $H_2SO_4$, then strong, fresh solution of $FeSO_4$, in such a way that the two fluids do not mix; shake then very gently; a brown color at junction shows $HNO_3$.

Add HCl; †

1. Effervescence and smell of $H_2S$ shows $H_2S$.
2. Effervescence and no smell shows $H_2CO_3$.

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* If $Hg_2$, Ag, or Pb are present, use $BaNO_3$ instead of BaCl.

† These reactions must have been noticed in testing for Bases.

# TABLES.

## TABLE OF EQUIVALENT VALUES AND USEFUL CONSTAN

1 meter = 39.3708 inches.
1 kilometer = 0.6214 mile.
1 square meter = 10.7643 square feet.
1 centimeter = 0.061 cubic inch.
1 liter = 61.027 cubic inches = 1.0567 quarts.
1 gram = 15.4323 grains.
1 kilogram = 2.2046 pounds.
1 kilogrammeter = 7.23308 foot-pounds.

1 cubic foot of water = 6.314 gals. at 4° C. weighs 62.425 lbs.
1 gallon of water at 17° C. weighs 10 lbs.
1 ton of water occupies 224 gallons, or 35.88 cubic feet.

## THREE FUNDAMENTAL UNITS.

A definite length — the Centimeter.
A definite mass — the Gram.
A definite time — the Second.

| | |
|---|---|
| Value of $g$ at London, in meters, per second | 9.817 |
| Value of $g$ at London, in feet, per second | 32.19 |
| Mean density of the earth | 5.67 |
| Mass of the earth in tons | $6 \times 10^{21}$ |
| Normal height of the barometer in mm. | 760 |
| Volume in liters of the molecular weight of a gas in grams | 22.32 |
| Double density of air (mass, 22.32 liters) | 28.872 |
| Mass of a liter of normal hydrogen in grams | 0.0896 |
| Percentage of oxygen in air by mass | 23.18 |
| Percentage of oxygen in air by volume | 20.9 |
| Mass of a liter of water at 4° C. in grams | 1000.13 |
| Mass of a cubic foot of water at 4° C. in lbs. | 62.425 |
| Latent heat of water | 79.25 |
| Latent heat of steam | 536 |
| Mechanical equivalent of the unit of heat (Kilog-met) | 425.434 |
| Mechanical equivalent of the unit of heat (foot-pounds) | 775.5 |

## TABLE SHOWING THE SOLUBILITY IN WATER AND ACIDS OF THE COMMON METALLIC SALTS.

| | Acetate. | Arsenate. | Arsenite. | Borate. | Bromide. | Carbonate. | Chlorate. | Chloride. | Chromate. | Cyanide. | Ferricyanide. | Ferrocyanide. | Fluoride. | Iodide. | Nitrate. | Oxalate. | Oxide. | Phosphate. | Silicate. | Sulphate. | Sulphide. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ag** | s | i | i | i | I | i | S | I | i | i | I | I | S | i | S | i | i | i | | s | i |
| **Pb** | S | i | i | i | sI | i | S | sI | i | i | s | i | s | i | S | i | i | i | i | I | i |
| **Hg$_2$** | s | i | i | | i | i | S | i | i | i | i | i | S | i | S | i | i | i | | s | i |
| **Hg** | S | i | i | | s | i | S | S | s | S | | | S | i | Si | i | i | i | | Si | i |
| **Bi** | S | i | | i | Si | i | S | Si | i | s | | I | s | Si | Si | i | i | i | | Si | i |
| **Cu** | S | i | i | i | S | i | S | S | s | i | I | I | s | Si | S | i | i | i | i | S | i |
| **Cd** | S | i | | s | S | i | S | S | i | i | i | | s | S | S | i | i | i | i | S | i |
| **Sn$''$** | S | i | i | i | S | | | Si | i | | i | i | S | S | Si | i | i | i | | S | i |
| **Sn$^{iv}$** | S | i | | | S | | | S | | | | i | S | Si | Si | S | i | i | | S | i |
| **Sb** | S | i | i | | Si | | | Si | i | | | | S | Si | | i | i | i | | Si | i |
| **Fe$''$** | S | i | i | i | S | i | S | S | | i | I | I | s | S | S | i | i | i | i | S | i |
| **Fe$^{iv}$** | S | i | i | i | S | | S | S | s | | S | I | s | S | S | s | i | i | i | S | i |
| **Cr** | S | i | | i | S | | S | S | i | i | | | s | S | S | S | i | i | i | S | i |
| **Al** | S | i | | i | S | | S | S | | | | | i | | S | i | i | i | | S | i |
| **Mn** | S | i | i | i | S | i | S | S | s | i | I | i | i | S | S | i | i | i | i | S | i |
| **Zn** | S | i | | i | S | i | S | S | S | i | i | i | s | S | S | i | i | i | i | S | i |
| **Co** | S | i | i | i | S | i | S | S | i | i | I | I | s | S | S | i | i | i | i | S | i |
| **Ni** | S | i | i | i | S | i | S | S | i | i | I | I | s | S | S | i | i | i | i | S | i |
| **Ba** | S | i | s | i | S | i | S | S | i | s | s | s | i | S | S | i | | i | i | I | S |
| **Sr** | S | i | s | i | S | i | S | S | s | S | | S | i | S | S | i | i | i | i | I | S |
| **Ca** | S | i | i | i | S | i | S | S | s | S | S | S | i | S | S | i | s | i | i | sI | S |
| **Mg** | S | i | i | s | S | i | S | S | S | S | S | S | i | S | S | s | i | i | i | S | S |
| **K** | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |
| **NH$_4$** | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | | S | | S | S |
| **Na** | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S |

*S*, soluble in water; *s*, sparingly soluble in water; *i*, insoluble in water, but made soluble by acids; *I*, insoluble in water or acids; *sI*, sparingly soluble in water, not transposed by acids; *Si*, soluble in acidulated water.

## ATOMIC WEIGHTS OF THE ELEMENTS.

An alphabetical list of the sixty-eight recognized elements, with their symbols and atomic weights, is here given for convenience of reference. The names of the rarer elements which are at present of little importance are printed in italics:—

| | | |
|---|---|---|
| Aluminium | Al | 27.4 |
| Antimony | Sb | 120 |
| Arsenic | As | 75 |
| Barium | Ba | 137 |
| *Beryllium* | Be | 9 |
| Bismuth | Bi | 210 |
| Boron | B | 11 |
| Bromine | Br | 80 |
| Cadmium | Cd | 112 |
| *Cæsium* | Cs | 133 |
| Calcium | Ca | 40 |
| Carbon | C | 12 |
| *Cerium* | Ce | 92 |
| Chlorine | Cl | 35.5 |
| Chromium | Cr | 52.5 |
| Cobalt | Co | 58.8 |
| Copper | Cu | 63.4 |
| *Didymium* | D | 95 |
| *Erbium* | E | 112.6 |
| Fluorine | F | 19 |
| Gallium | Ga | 69 |
| *Glucinum* | Gl | 14 |
| Gold | Au | 196 |
| Hydrogen | H | 1 |
| *Indium* | In | 113.4 |
| Iodine | I | 127 |
| *Iridium* | Ir | 198 |
| Iron | Fe | 56 |
| *Lanthanum* | La | 93 |
| Lead | Pb | 207 |
| *Lithium* | Li | 7 |
| Magnesium | Mg | 24 |
| Manganese | Mn | 55 |
| Mercury | Hg | 200 |
| *Molybdenum* | Mo | 96 |
| Nickel | Ni | 58.8 |
| *Niobium* | Nb | 94 |
| Nitrogen | N | 14 |
| *Osmium* | Os | 199 |
| Oxygen | O | 16 |
| *Palladium* | Pd | 106.5 |
| Phosphorus | P | 31 |
| Platinum | Pt | 197.4 |
| Potassium | K | 39.1 |
| *Rhodium* | Rh | 104 |
| *Rubidium* | Rb | 85.7 |
| *Ruthenium* | Ru | 104 |
| *Samarium* | Sm | 150 |
| *Scandium* | Sc | 44 |
| *Selenium* | Se | 79.5 |
| Silicon | Si | 28 |
| Silver | Ag | 108 |
| Sodium | Na | 23 |
| *Strontium* | Sr | 87.5 |
| Sulphur | S | 32 |
| *Tantalum* | Ta | 182 |
| *Tellurium* | Te | 128 |
| *Terbium* | Tb | 148.5 |
| *Thallium* | Tl | 204 |
| *Thorium* | Th | 231.4 |
| Tin | Sn | 118 |
| *Titanium* | Ti | 50 |
| *Tungsten* | W | 184 |
| *Uranium* | Ur | 120 |
| *Vanadium* | V | 51.3 |
| *Yttrium* | Yt | 61.6 |
| Zinc | Zn | 65 |
| *Zirconium* | Zr | 89.6 |

# SCIENCE.

*"Thinking again the thoughts of God."*

## *Organic Chemistry:*

*An Introduction to the Study of the Compounds of Carbon.* By IRA REMSEN, Professor of Chemistry, Johns Hopkins University, Baltimore. Adapted to the needs of all students of Chemistry, whether they intend to follow the pure science, or to deal with it in its application to the arts, medicine, etc. 5¼ × 7½ inches. x + 364 pages. Cloth. Price by mail, $1.30; Introduction price, $1.20.

THIS book is strictly an *introduction* to the study of the compounds of Carbon, or Organic Chemistry, and is intended to meet the wants of students in our scientific schools, medical schools, schools of technology, and colleges. It is difficult to see how, without some such general introductory study, the technical chemist and the student of medicine can comprehend what is usually put before them under the heads of "Applied Organic Chemistry" and "Medical Chemistry." The book is perhaps rather more elementary than most of the existing small books on the subject, and is therefore, it is believed, better adapted to the classes of students mentioned. It takes nothing for granted except an elementary knowledge of General Chemistry. Special care has been taken in selecting for treatment such compounds as will best serve to make clear the fundamental principles. General relations as illustrated by special cases are discussed rather more fully than is customary in books of the same size; and, on the other hand, the number of compounds taken up is smaller than usual, though all which are of real importance to the beginner are treated of with some degree of fulness. Thus there is less danger of confusion than when a larger number is brought to the attention of the student. The author has endeavored to avoid dogmatism, and to lead the student, through a careful study of the facts, to see for himself the reasons for adopting the prevalent views in regard to the structure of the compounds of carbon. Whenever a new formula is presented, the reasons for using it are given so that it may afterward be used intelligently. Full directions are given for making a number of typical compounds, by methods quite within the reach of every chemical laboratory, so that with the aid of the book a systematic course of laboratory work on carbon compounds may be carried on.

The following description of the book, which is also a noteworthy commendation of it, we quote from a review of it by **Prof. M. M. Pattison Muir**, Cambridge University, Eng., published in *Nature*, London, June 4, 1885.

"This is chemistry. Of how few books professing to be books on chemistry can it be said that they teach us anything of the science! The student who begins with the study of the carbon compounds has to suffer many things from the text-books. Some of them present him with dry bones in the shape of isolated facts, and bold assertions regarding structural formulæ and the linking of atoms. Others lead him into speculations which he is unprepared to follow; he makes little flights into these, and comes back fancying he is a chemist. Other books (there are not many of them) proceed on the true scientific lines; but very frequently their pages are encumbered with too many facts about more or less widely separated compounds, or they deal so much with groups of compounds, rather than with the typical individual bodies, that the beginner soon loses his way, becomes perplexed, and is ready to abandon the pursuit.

"Prof. Remsen has shown us a more excellent way than any of these. He leads the learner by degrees through the early difficulties; he places before him distinct and detailed accounts of a few typical compounds; he shows him how these compounds are mutually related; and then he takes him back to the beginning again, and teaches him how each compound he has learned to know represents a group, and how, when he knows the properties of one member of the group, he also knows much about all the members.

"At the outset Prof. Remsen makes a few wise and pregnant remarks on the meaning of the structural formulæ. These 'enable the chemist who *understands* the language in which they are written to see relations which might easily escape his attention without their aid. In order to *understand* them, however, the student must have a knowledge of the reactions upon which they are based; and he is warned not to accept any chemical formula unless he can see the reasons for accepting it.' The whole book is a practical sermon on this text.

"In no other elementary book in the English language will the student find so many admirably chosen examples of the formation of structural formulæ. The important facts are noted; then the inference is drawn; then the hypothesis is ventured upon; analogous facts are recalled; the hypothesis is strengthened or weakened; suggestions are made; experiments are conducted; and all is finally summarized in the formula. But the book is more than a selection of examples showing how structural formulæ ought to be gained. It is a systematic although elementary treatise on organic chemistry. The student is first taught about the two paraffins, methane and ethane; then he learns how the halogen derivatives of these are prepared, and what relations they bear to the parent hydrocarbons. By this time he has had his first taste of isomerism. Then he proceeds to the oxygen derivatives of methane and ethane; he learns what an alcohol is; he becomes acquainted with ether, aldehyde, formic, and acetic acids, some ethereal salts, and acetone. This method of studying a few simple compounds in detail is pursued until the student is more or less familiar with representatives of all the principal groups of compounds derived from the paraffins. He is now in a position to study these hydrocarbons as a group, and to deal in some detail with the questions of isomerism. When the paraffins and their derivatives have been thus studied, the more difficult subject of the benzenes and their compounds is approached. And here the author shows an admirable power of dealing with facts as facts, and with theories as theories.

"Many admirable illustrations of the scientific method of inquiry are to be found throughout the book. I would especially draw attention to the simple but thorough-going treatment of the 'equivalency of the hydrogen atoms' in the molecule $CH_4$ (pp. 28, 29) and in the molecule $C_6H_6$ (pp. 234–236). It is on subjects such as are discussed in the pages referred to that the chemical student so frequently suffers shipwreck. If he will use this little book by Prof. Remsen as his pilot, and will keep a good lookout as he proceeds, he may hope to pass the shoals of the hexagon-formula and the shallows of the ortho-, meta-, and para-derivatives of benzene.

"The author of this book deserves the thanks of all chemical teachers who have tried to teach organic chemistry to beginners for the clear and short directions which he gives for preparing the important compounds of carbon. The book may well be used as a laboratory guide no less than an introduction to the science of organic chemistry."

***The book is now used in many of the leading colleges of America. Three editions of it have been sold for the English market. It has been translated into German, and is now being translated into Italian. These facts, together with the following letters, show that the book has already taken high rank on both sides of the Atlantic:—***

**D. Mendeleeff**, *Prof. of Chemistry in the Univ. of St. Petersburg, Russia:* The elements of organic chemistry are treated in the book in a manner so novel and so instructive that I look forward with confidence to seeing it translated into other languages. (*Nov.* 25, 1885.)

**M. M. Pattison Muir**, *Prof. of Chemistry, Cambridge Univ., England:* A great many students in this university are using the book; indeed, I think it will soon be used in preference to any other elementary work on the subject of which it treats. (*Nov.* 18, 1885.)

See also the fuller opinion of Prof. Muir, given on page 2.

**Alex. Crum Brown**, *Prof. of Chemistry, Univ. of Edinburgh, Scotland:* I have delayed writing till I had read the book carefully and had some experience of its use by students. That I have now had, and I find it a very excellent text-book for students attending my lectures on organic chemistry. I was particularly struck with the admirable way in which important suggestions are made, with great economy of space, by the "Notes for Students." (*Dec.* 22, 1885.)

**Dr. Lothar Meyer**, *Prof. of Chemistry, Tübingen:* Although I have as yet examined it but imperfectly, I can nevertheless say that the method followed in it is the right one, particularly in making perfectly clear to students the grounds of our prevailing theoretical views. It is just in this particular that most of our text-books are deficient. (*June* 23, 1885.)

**Arthur W. Wright**, *Prof. of Chemistry, Yale Coll.:* It is admirably arranged and executed, and cannot fail to be a most important aid to the study of organic chemistry, both to student and teacher. (*May* 25, 1885.)

**R. H. Chittenden**, *Prof. of Physiological Chemistry, Yale Coll.:* In my opinion it is the best guide to the study of organic chemistry in the English language. (*June* 29, 1885.)

**Wm. G. Mixter**, *Prof. of Chemistry, Yale Coll.:* It is the best book with which I am acquainted for beginners in the study of organic chemistry. (*June* 15, 1885.)

**Albert B. Prescott**, *Prof. of Organic and Applied Chemistry, Univ. of Mich.:* It is already in use by my class in the department of medicine of this University. So far as I have tested its use as an aid in teaching beginners, I prefer it to any other book. (*April* 8, 1885.)

**John W. Langley**, *Prof. of General Chemistry, Univ. of Mich.:* I regard it as the best elementary manual on this subject in the English language. (*July* 3, 1885.)

**C. F. Chandler**, *Prof. of Chemistry, Columbia Coll.:* It is an admirable book, and will be the greatest comfort to teachers. (*April* 7, 1885.)

**J. S. Schanck**, *Prof. of Chemistry, Princeton Coll.:* I have examined this work sufficiently to satisfy me that it is likely to be the most useful of all Prof. Remsen's productions. (*April* 9, 1885.)

**W. L. Goodwin,** *Prof. of Chemistry, Queen's Univ., Kingston, Canada:* I have decided to recommend it to my students. It is very satisfactory, combining clear exposition with practical hints which are of the greatest educational value. I have long been looking for such a text-book. (*April* 9, 1885.)

**N. T. Lupton,** *Prof. of Chemistry, Vanderbilt Univ.:* I am delighted with it. The arrangement is systematic, the language clear and concise, the experiments well selected; and, in fact, the whole subject is presented in an unusually attractive manner. (*June* 10, 1885.)

**F. A. Genth,** *Consulting and Analytical Chemist, Univ. of Penna.:* I have found it to be one of the best books ever published for the class of students for which it is intended. It gives me great pleasure to recommend it most highly. (*Aug.* 15, 1885.)

**Wm. A. Noyes,** *Prof. of Chemistry, Univ. of Tenn., Knoxville:* I expect to use the work with my classes next year. (*April* 7, 1885.)

**LeRoy C. Cooley,** *Prof. of Physics and Chemistry, Vassar Coll.:* I find in it the best outline of this branch of science which I have ever seen. (*April* 27, 1885.)

**J. I. D. Hinds,** *Chair of Chemistry, Cumberland Univ.:* I have a class of twenty young men now studying it. I am delighted with it, and do not hesitate to pronounce it the best work on the subject for college classes that I have seen. (*Feb.* 17, 1886.)

**Henry M. Seely,** *Prof. of Chemistry, Middlebury Coll.:* I am confirmed in the impression I got from a portion of the advance sheets, that it is the very best introduction to the study of organic chemistry yet published. (*April* 8, 1885.)

**Wm. Ripley Nichols,** *Prof. of General Chemistry, Mass. Inst. of Tech.:* I like the plan of the book very much; and if I taught organic chemistry, I should want no better introduction to the subject. (*July* 8, 1885.)

**F. W. Clarke,** *Chief Chemist of U. S. Geological Survey:* It impresses me as being the best book of the kind I have yet seen. It ought to find speedy favor with the teachers of advanced chemistry. (*July* 11, 1885.)

**E. T. Fristoe,** *Prof. of Chemistry, Columbian Univ., Washington, D.C.:* It is the only book I have ever seen that treats the organic bodies properly. I have used about twenty-five copies this year, and will need more next year. (*June* 10, 1885.)

**W. Simon,** *Prof. of Chemistry, Maryland Coll. of Pharm., Baltimore:* I shall not fail to recommend the book to all of my students who can use a work of its kind. (*May* 18, 1885.)

**Floyd Davis,** *Prof. of Chemistry, Virginia Agricultural and Mechanical Coll.:* The author has happily blended theory and practice so well that I anticipate the subject of organic chemistry will soon be considered no more difficult to master than the general principles on which it is founded. I believe that schools of technology will find this an excellent text-book. (*April* 27, 1885.)

**Charles F. Himes,** *Prof. of Chemistry, Dickinson Coll., Penna.:* It is an admirable text-book in every particular. (*June* 1, 1885.)

**F. F. Jewett,** *Prof. of Chemistry and Mineralogy, Oberlin Coll.:* It is a very superior text-book. It is no easy task to select from the vast amount of material so rapidly furnished by modern chemical research just that which ought to enter into a text-book of this kind, and yet to present enough, in an interesting way, to illustrate and teach the truths and principles of organic chemistry. This, however, Prof. Remsen has done in a masterly manner. I am sorry I have not a class in organic chemistry into whose hands I can put this model text-book. (*Aug.* 17, 1885.)

**T. H. Norton,** *Prof. of Chemistry, Univ. of Cincinnati:* During the coming year I shall place it in the hands of those students in my department who take up organic chemistry without the intention of devoting themselves to chemistry as a profession. I regard the work as presenting in a clear and concise manner as much of the fact and theory of organic chemistry as a well-educated man needs. The experimental feature is excellent, and forms a step in advance of the rapidly increasing manuals of experimental work in inorganic chemistry. (*June* 10, 1885.)

**Theo. Sterling,** *Prof. of Chemistry, Kenyon Coll., Gambier, O.:* It is, as one would expect from Prof. Remsen, an excellent text-book; and should I have occasion to use a text-book on that subject, I should certainly adopt this one. (*April* 12, 1885.)

**Charles F. Mabery,** *Prof. of Chemistry, Case School of Applied Science, Cleveland, O.:* After a careful examination I am convinced that it contains just such an exhaustive treatment of the structure of the carbon compounds as is needed to correct erroneous impressions and to clear away misty ideas that are too commonly held concerning theoretical organic chemistry. (*July* 10, 1885.)

**John A. Myers,** *Prof. of Chemistry, Agricultural and Mechanical Coll. of Mississippi, and State Chemist:* When I have any students who wish to take an advanced course in chemistry, I shall use the work. (*May* 25, 1885.)

**E. H. S. Bailey,** *Prof. of Chemistry, Univ. of Kansas, Lawrence:* I like it. As an *introduction* to the study of organic chemistry it certainly will prove an invaluable help to the instructor. (*April* 17, 1885.)

**A. Litton,** *Prof. of Chemistry, St. Louis Medical Coll.:* In my opinion it is the best introduction to the study of organic chemistry that I have seen. (*May* 22, 1885.)

**F. P. Venable,** *Prof. of Chemistry, Univ. of N. C.:* I am greatly pleased with the book. If practicable, I may introduce it in my classes here. (*Feb.* 1, 1886.)

**W. L. Martin,** *Prof. of Chemistry, Davidson Coll., N.C.:* I used it last spring after it came out, and this year I have put a second class through it. It is the very best elementary text-book on the subject I ever saw; and one of the best I think on any subject. It is simply a *model* text-book. (*May* 25, 1886.)

**J. A. Burns,** *Prof. of Chemistry, Southern Medical Coll., Atlanta, Ga.:* It more than meets my expectations. It is *clear, concise, and practical.* It really supplies a long-felt want on the part of teachers who are attempting to enlighten the understanding, without confusing the memory, by bringing their students into actual contact with the things studied. I shall use it in the lecture-room and in the working laboratory. (*June* 6, 1885.)

**Eugene A. Smith,** *Prof. of Chemistry and Geology, Univ. of Ala., Tuscaloosa:* I shall introduce it into my junior class here next session. It appears to me to be the best book yet published for use with beginners; and there is no subject which gives more trouble to beginners. (*July* 4, 1885.)

# *The Elements of Inorganic Chemistry:*

*Descriptive and Qualitative.* A Text-Book for Beginners, based on Experimental and Inductive Methods. By JAS. H. SHEPARD, Instructor in Chemistry, Ypsilanti High School, Mich. 5¼ by 7½ inches. xx + 377 pages. Cloth. Price by mail, $1.25. Introduction price, $1.12.

IT is a practical embodiment of **the modern spirit of investigation.** It places the student in the position of an investigator, and calls into play mental faculties that are too often wholly neglected. It leads him *to observe*, *to experiment*, *to think*, *to originate*. Coming as it does from the working laboratory of a practical instructor, who has had the constant advice of fellow-teachers in all parts of the country, this text may be fairly taken as an exponent of the latest methods of teaching chemistry.

Its distinctive features are: experimental and inductive methods; the union of descriptive and qualitative chemistry, thus allowing these kindred branches to supplement and illustrate each other; a practical course of laboratory work, illustrating the general principles of the science and their application; a fair presentation of chemical theories, and a conciseness which confines the work to the required limits.

Each element and compound is treated in the following natural manner: —

1. *Its occurrence*, in which the student learns where he may find it.
2. *Its preparation*, or how he may obtain it for examination.
3. *Its properties* and *uses*.
4. *Its tests*, or how he may detect its presence in known or in unknown substances.

Many equations are given to illustrate the chemical reactions in the different operations, and there are also special directions for detecting the acids as well as for separating the metals into groups, and isolating the individuals from each group.

The work closes with full and explicit directions for successfully and economically equipping the laboratory, and preparing the needed reagents and solutions.

Teachers who are compelled to compress their work into a few weeks' course can adopt the "Briefer Course" outlined in the preface, and have meanwhile the benefit of a book sufficiently complete to cover any want likely to arise in the laboratory. But average pupils of sixteen years can do all the work laid down in this text. A fair class can do the whole work up to the metals in twenty weeks, and all the work given in metals in eight or ten weeks.

We confidently recommend Shepard's Chemistry to any teacher who now uses, or who wishes to adopt, the laboratory method of instruction.

Among its many new and valuable features, a prominent teacher specifies the following: —

1. Its *excellent methods*, which bring out the great educational force of the science, and yield exceptionally large practical results.

2. The *logical arrangement* of its subject-matter, introducing the principles of the science by easy steps.

3. Its *conciseness* and its *completeness* fully covering the beginner's wants in the working laboratory.

4. Its *mechanical excellence*, the typography being open and attractive, and the large type allowing the text to be read at a distance without injury to the eyes; the binding being such that the book will stay open on the desk while the student is at work, and the color of the cloth being such as is least affected by acids.

5. *The Appendix*, which gives (1) Instructions for equipping the laboratory; (2) Directions for preparing all needed reagents; (3) A complete list of working materials; (4) The impurities found in commercial reagents; (5) All the names by which reagents are known.

The book is based upon plans and methods which have been employed in the author's laboratory throughout a series of years, and no work has been incorporated in the text or in the exercises that has not there been proven practicable.

A wide correspondence with the best teachers in all parts of the country shows that they are pursuing essentially the same plan. Throughout the book the aim is to make the labors of the teacher as light as possible, and to "place the laboratory work where it will do the most good in the hands of the students."

"This work and Remsen's Organic Chemistry (page 1 of this catalogue) form an admirable course for the presentation to the student of the facts of inorganic and organic chemistry." — CURTIS C. HOWARD, *Prof. of Chemistry, Starling Med. Coll., Columbus, O.*

☞ A Circular, suggesting various plans of shortening the course, as well as a Special Circular, of interest to chemists and teachers of chemistry, will be sent on application to the publishers.

***The following hearty endorsements are taken from our Special Circular on this book, and show the unanimity of opinion among competent judges, in all sections of the country, as to its timeliness, its value, and its success in actual use:—***

## FROM THE COLLEGES.

**Ira Remsen,** *Prof. of Chemistry, Johns Hopkins Univ.:* It seemed to me that the book was likely to prove useful in showing teachers how they could keep their pupils profitably at work in the laboratory from the beginning of their study. The lesson taught by the book is that chemistry can only be learned in the laboratory, and that the book is only a guide to experimental work; and this is a lesson which certainly needs to be taught above all others in chemistry. (*May* 24, 1886.)

**Arthur W. Wright,** *Prof. of Chemistry, Yale Coll.:* The portion received (120 pages) impressed me very favorably, both as to the method of developing the subject, and the selection of topics. If the whole book is as good, it must be an excellent treatise for a beginner in chemistry, and a valuable aid to the teacher. (*May* 15, 1886.)

**Herbert E. Smith,** *Prof. of Chemistry, Yale Coll.:* I believe that a class that could work through the prescribed course would gain an unusually good knowledge of the subject. (*May* 15, 1886.)

**Dr. William E. Lockwood,** *Ass't in Chemistry, Med. Dept., Yale Coll.:* I take pleasure in commending it as a very thorough elementary work. (*Feb.* 19, 1886.)

Since writing the above, I have used the book to some extent, and greater familiarity confirms my first impression of its merits. (*May* 11, 1886.)

**Horace L. Wells,** *Instr. in Anal. Chemistry, Sheffield Scientific School, New Haven:* My opinion of it is a favorable one. (*Feb.* 16, 1886.)

**C. F. Chandler,** *Prof. of Chemistry, Columbia Coll.:* I have looked it through with a great deal of interest, and find it to be an excellent book. The system is very well chosen, careful selection has been made in the presentation of facts and experiments, the equations are always well presented, and a great degree of accuracy characterizes the entire work. (*May* 13, 1886.)

**L. H. Laudy,** *Ass't Prof. of Chemistry, Columbia Coll.:* It is not possible to place before the student in chemistry a more logical and concise work, and I feel confident that it will meet with general approval. (*Jan.* 30, 1886.)

**C. A. Schæffer,** *Prof. of General Chemistry, Cornell Univ.:* After a careful examination of the contents, it gives me great pleasure to pronounce it excellent. The plan is well conceived and embodies the method, by all means the best, of imparting in a thorough manner, the first ideas of chemistry to the student. In short, I have been very much pleased with it, and shall very gladly recommend it to all beginners. (*March* 4, 1886.)

**John W. Langley,** *Prof. of Chemistry, Univ. of Michigan:* It is clearly and succinctly written. (*Dec.* 14, 1885.)

**Albert B. Prescott,** *Director of the Chemical Laboratory, Univ. of Michigan:*

It will prove a valuable aid in teaching chemistry in the high schools. (*Dec.* 17, 1885.)

**Otis C. Johnson**, *Ass't Prof. of Applied Chemistry, Univ. of Michigan:* I am very much pleased with it. I like it so well I have nothing to say by way of criticism. (*Oct.* 23, 1884.)

**J. S. Schanck**, *Prof. of Chemistry, Princeton Coll.:* I consider it one of the very best among the multitudes of small works of late issue. (*Nov.* 23, 1885.)

**Edward Hart**, *Prof. of Chemistry, Lafayette Coll.:* It is a good book. I have heard a great many warm praises of it from my friends in the profession, and like it very much myself. (*May* 29, 1886.)

**W. O. Atwater**, *Prof. of Chemistry, Wesleyan Univ., Middletown, Conn.:* My assistants and some of our students who have had experience in teaching, as well as myself, are very highly pleased with it. The method and spirit of the work, and especially the way in which it leads the student to study the phenomena of chemistry for himself, and to note, collate, and compare the results of his observations, seem to me particularly fortunate. One of the most cheering signs of the times for the study of the sciences of nature seems to me to be not only the appearance of such books as this, but the very cordial reception and rapid introduction which they are finding in our schools. (*Feb.* 10, 1886.)

**S. E. Tillman**, *Prof. of Chemistry, U. S. Mil. Acad., West Point:* The introductory statements to teachers I regard as unusually sound, and I have no doubt that the book will prove satisfactory where the conditions admit its use as directed. (*Nov.* 30, 1885.)

**Chas. E. Munroe**, *Prof. of Chemistry, U. S. Naval Acad., Annapolis:* It is an excellent introduction to the study of the science, and is well arranged for the courses of instruction in such high and normal schools as possess facilities for laboratory work and have special instructors in chemistry. (*March* 20, 1886.)

**Maurice Perkins**, *Prof. of Anal. Chemistry, Union Coll.:* I am much pleased with it. It is far superior to the majority of text-books of its size. If I were commencing with a class, I should be tempted to use it. (*Jan.* 3, 1885.)

**J. F. McGregory**, *Prof. of Chemistry, Madison Univ., N.Y.:* Its excellent arrangement, and the clearness with which facts are explained, together with the evident care with which the book has been prepared, should place it at once in the front rank of elementary chemical text-books. (*Feb.* 1, 1886.)

**Edwin J. Bartlett**, *Prof. of Chemistry, Dartmouth Coll.:* It gives me pleasure to express my appreciation of so excellent a book. I like especially the large number of experiments for the pupil, and the constant stimulus to establish facts by additional experiments of his own. The book seems, while abounding in details, to be admirably adapted to teachers whose experience has been limited, as well as to others. (*Feb.* 10, 1886.)

**A. E. Dolbear**, *Prof. of Physics, Tufts Coll.:* Shepard's Chemistry commends itself to me for its method. The experiments for the pupil to perform are simple and appropriate, and ample enough for beginners. Theoretical chemistry is developed as far as it is profitable to carry it in a book for beginners, and for such it is a very suitable book. (*March* 7, 1886.)

**Mrs. Ellen H. Richards**, *Instructor in Chemistry, Institute of Technology, Boston:* The author deserves the hearty thanks of the many teachers who are called upon to give elementary instruction in chemistry, not as an introduction to a professional career, but as a part of a general education, and as an illustration of the application of science to daily life. (*Dec.* 21, 1885.)

**Maria S. Eaton**, *Prof. of Chemistry, Wellesley Coll.:* All of our teachers of chemistry have examined Shepard's book with interest. It is very well arranged, attractive, and has features of special interest. I think it will be very successful. (*March* 13, 1866.)

**Peter T. Austen**, *Prof. of Chemistry, Rutgers Coll.:* In subject-matter and arrangement it is remarkably well adapted to use in schools and in courses of general instruction. I wish the book every success. (*Feb.* 3, 1886.)

**Edward H. Keiser**, *Prof. of Chemistry, Bryn Mawr Coll., Pa.:* It is a great improvement on the older text-books on elementary chemistry. I take pleasure in heartily recommending it to all who are beginning the study of chemistry. (*Jan.* 30, 1886.)

**Richard C. Stanley**, *Prof. of Chemistry, Bates Coll., Me.:* I have carefully considered the plan and method of this work, and am pleased with both. It is clear, concise, and to the point, containing all that an elementary text-book should contain, and having nothing superfluous. I recommend it most heartily to our high schools and academies. (*Feb.* 2, 1886.)

**A. B. Auberl**, *Prof. of Chemistry, Maine State Coll.:* I am convinced of its value as a text-book. (*Feb.* 25, 1886.)

**Harry D. Campbell**, *Asst. Prof. of Chemistry, W. and L. Univ., Va.:* I consider it much superior to most elementary chemistries. We employ in our institution essentially the method of instruction recommended by the author. (*Dec.* 23, 1885.)

**L. L. Holladay**, *Prof. of Chemistry, Hampden Sidney Coll., Va.:* I have not seen a work of its kind in a long time which has pleased me as much as this one. I commend it most heartily. (*Jan.* 30, 1886.)

**Wm. A. Shepard**, *Prof. of Chemistry, Randolph-Macon Coll., Va.:* It is an excellent and accurate treatise, and especially well adapted for the use of students who wish a general knowledge of the subject. (*May* 20, 1886.)

**Floyd Davis**, *Prof. of Chemistry, Agr. and Mech. Coll., Va.:* For giving the salient points of the science, and for instruction preparatory to an advanced course in analytical chemistry, I consider this work superior to any other of its size with which I am acquainted. (*Feb.* 6, 1886.)

**F. P. Venable**, *Prof. of Chemistry, Univ. of N. C.:* I read the book through with great interest. The method adopted is new, and is undoubtedly the most sensible, practical way of giving instruction in the science. The book ought to be widely used among our schools and colleges. (*Feb.* 1, 1886.)

**W. B. Burney**, *Prof. of Chem., Univ. of S.C.:* I regard it as much superior to the majority of the little books of its kind, with which the market is flooded. (*June* 12, 1886.)

**H. C. White**, *State Chemist, and Prof. of Chemistry, Univ. of Georgia:* It is, in my opinion, an excellent work for high school and academy use. I have already recommended it to several excellent teachers, who inform me they shall use it in their schools. (*Feb.* 23, 1886.)

# The Laboratory Note-Book.

*For Students using any Chemistry.* 4¾ by 7¼ inches. Board covers. Cloth back. 192 pp. Price by mail, 40 cts.; Introduction price, 35 cts.

IT contains blanks for experiments; blank tables for the reactions of the different metallic salts; pages for miscellaneous matter; and an extra chart for the natural classification of the elements similar to that on page 221 of Shepard's Chemistry. This may be rolled into a cylinder by the student.

The advantages of using this note-book are, briefly, these: It saves time for the student; its size is convenient; and it is cheaper than an ordinary blank-book. The paper is such that it readily takes ink without blotting or smearing, and it may be used with a lead pencil.

The value of systematic note-taking by the student in chemistry can hardly be over-estimated. The careful analyst habitually keeps record of his work, and thus the greater portion of our most valuable chemical literature has originated. If the expert finds his notes to be of inestimable value to him, what shall we say in the case of the beginner? Evidently, that he should form, at the very outset, those habits which will tend to make him accurate, and which will insure his after-success.

In the note-book the teacher has a most potent ally; for, through its aid, he may know just how his students are doing their work, and can therefore better adapt his teaching to their needs.

Our Special Circular contains fac-similes of three pages, prepared by the students in the Ypsilanti high school for 1885–6, showing how the book is to be used.

**Robt. B. Warder**, *Prof. of Chemistry, Purdue Univ., Lafayette, Ind.*: It strikes me very favorably. I think further examination may lead me to introduce it in Purdue University next fall. (*Apr.* 24, '86.)

**F. J. Roche**, *Prof. of Chemistry, University Coll., Toronto, Ont.*: I have been struck with the excellence of the second part as a means of tabulating results of simple qualitative analysis,—something most students sadly need. (*May* 15, 1886.)

**Chas. W. Hargitt**, *Prof. of Natural Science, Moore's Hill Coll., Ind.*: I like the plan very well for the purpose intended. (*April* 24, 1886.)

**A. Wanner**, *Prin. of York High School, Pa.*: Laboratory Notes in the hands of students will encourage *systematic* experiment. It is a good book for beginners, who have not the experience yet to enable them to judiciously use a blank-book. It not only will lead to frequent reference to the chemistry used, but will cultivate a habit of *accurately, clearly,* and *briefly* recording known conditions. (*March* 1, 1886.)

# *The Elements of Chemical Arithmetic,*

*with a Short System of Elementary Qualitative Analysis.* By J. MILNOR COIT, M.A., Ph.D. 7½ by 5 inches. iv + 89 pages. Cloth. Price by mail, 55 cents; Introduction price, 50 cents.

THIS manual is designed to supplement the teaching of ordinary text-books of descriptive chemistry. It is the result of the author's own experience in elementary science-teaching, and has been successfully used by him in his own classes. The methods have therefore been practically tested. Part I. contains the more important rules and principles of chemical arithmetic, followed by a series of problems. The matter in this part of the book is purposely very much condensed, and brought within the scope of the average student in high schools or colleges.

Part II. contains a short system of elementary qualitative analysis. The simplest and best tests have been adopted, and the tables of separation of the metals will be found to be the least complicated. Some tables for reference will be found at the end of the book.

The manual will invite the examination of those who are interested in making the teaching of chemistry more practical even to beginners. It is suggested that the book be used together with a good work in descriptive chemistry. In the preparation of this manual the writer has had the benefit of the advice and suggestions of several eminent and experienced teachers.

***Though issued so recently, the following opinions have come to hand:—***

**A. S. Hall,** *Prof. of Chemistry, U.S. Naval Acad., Annapolis, Md.:* I am very much pleased with the arrangement of the first part. It is presented in such a simple way as to render it well adapted to schools in which elementary sciences are taught. (*May* 22, 1886.)

**T. H. Norton,** *Prof. of Chemistry, Univ. of Cincinnati, O:* It is admirably written, and I regard it as well adapted to supplement the ordinary descriptive text-book or series of lectures, especially for high-school training preparatory to scientific courses. (*May* 12, 1886.)

**W. K. Higley,** *Prof. of Chemistry, Univ. of Chicago:* I like it very much. We shall use it next year in our laboratory, and I have recommended it to this year's students. (*June* 5, 1886.)

**John W. Fox,** *Prof. of Chemistry, Georgetown Coll., D.C.:* It is an excellent little book. (*May* 15, 1886.)

**J. W. Holland,** *Prof. of Chemistry, Jefferson Medical Coll., Philadelphia, Pa.:* It is an excellent manual, and will be of great service to teacher and pupil. (*June* 5, 1886.)

**A. R. Whitehill**, *Prof. of Chemistry, West Virginia Univ.:* I am much pleased with it. (*May* 19, 1886.)

**John A. Myers**, *State Chemist, and Prof. of Chemistry, Agricultural Coll., Miss.:* I think both (Shepard's and Coit's) works are superior text-books, and feel disposed to adopt Coit's. My class will use such a work during the last two terms. (*May* 26, 1886.)

**S. E. Jones**, *Prof. of Natural Science, Carson Coll., Tenn.:* It is simply unsurpassed. (*May* 27, 1886.)

**H. A. Cottell**, *Prof. of Chemistry, Univ. of Louisville, Ky.:* I am pleased with the book, and believe that I can recommend it to my classes. (*May* 25, 1886.)

**Eugene A. Smith**, *Prof. of Chemistry, Univ. of Alabama:* It appears to me to be a first-rate little book. It can be used to advantage in almost any laboratory. (*June* 4, 1886.)

**W. W. Thoburn**, *Prof. of Chemistry, Wesleyan Univ., Bloomington, Ill.:* Coit's little book will meet with a demand in this corner of the school world. If it had been issued two months earlier, my class would be using it this term. I will introduce it next year. That part of the book given to chemical arithmetic is a complete yet brief review of the mathematical phase of chemistry, and is very suitable for students entering the subject of qualitative analysis. I have put the book you sent me into the hands of some of my working chemists during the past week, and note with pleasure and interest its adaptability to classes of this grade. (*May* 31, 1886.)

**W. Z. Bennett**, *Prof. of Chemistry, Univ. of Wooster, O.:* I have examined it quite carefully, and am much pleased with it. The first part of the work supplies a real need. I think I may use the book in my classes. (*May* 24, 1886.)

**A. M. Beal**, *Prof. of Chemistry, Western Coll., Toledo, Ia.:* It is a very commendable work. Am particularly pleased with the author's clear and concise system of elementary qualitative analysis. Shall take pleasure in using the work in my next class. (*May* 26, 1886.)

**C. Dwight Marsh**, *Prof. of Chemistry, Ripon Coll., Wis.:* I am pleased with it, and think it would be an excellent hand-book for high-school classes. (*June* 4, 1886.)

**L. A. Rogers**, *Instructor in Natural Science, High School, New Britain, Conn.:* The tables, which are those in general use, make the book a valuable supplement, and will be received by the chemist as an excellent text-book in his instruction. The qualitative analysis of metals, with all that it involves in working out chemical reactions, is the one thing that gives a living interest in the study. (*May* 5, 1886.)

**New England Journal of Education**: Small as the work is, it is a *multum in parvo* of chemical science. There is not a superfluous word in the whole book. Its definitions are curt and incisive. It is divested of all verbiage, and even seems to grudge a minute's delay in getting into the subject. Concise as it is, it is also clear and perspicuous. The author is to be congratulated for the production of this able book. It will go hard with our youth if with such books they try to escape the calamity of knowing something. (*May* 27, 1886.)

**Cleveland Leader**: It is assured at the start of a practical success. Even its brevity will commend it when the wonderful extent of its study is understood. (*May* 16, 1886.)

**Education, Boston**: Its definitions are admirable for their directness and simplicity. (*June*, 1886.)

# *First Book in Geology.*

By N. S. SHALER, Professor of Paleontology, Harvard University. 5¼ by 7½ inches. Cloth. xvii + 255 pages, with 130 figures in the text. 74 pages additional in Teacher's Edition. Price by mail, $1.10; Introduction, $1.00.

THE design of this book is to give the student from ten to fifteen years of age a few, clear, well-selected facts that may serve as a key to the knowledge of the earth. The number of facts dealt with is far less than is usually given in such books, but pains is taken in their presentations to make them open the way to the broadest veins that the science affords. The aim is to illustrate the principles of geology by reference to as many facts of familiar experience as possible.

The first part of the book treats of the simpler phenomena of a physical sort, the movements of the water and the air, and their effect on the machinery of the earth's surface; then the simpler underground actions are taken up, such as the formation of veins, the folding of mountains, and the forces that lead to earthquakes and volcanoes. The latter half of the book is given to the history, in outline, of the earth's organic life. This is treated in a very general way, in order to show the student only the great steps of advance, and the method in which they are accomplished.

In the appendix is a brief account of certain more important mineral species, arranged to give the student an outline of mineralogy, and some idea of the common uses of minerals.

The Teacher's Edition contains seventy-four pages of directions for those who use the book in class instruction. First there are general directions for the guidance of teachers in their work in natural history, then each chapter of the book is taken up in turn, and the instructor is told how to supplement each lesson, by reference to facts that may be easily accessible in the nature about the school.

The instructor who will make proper use of these pages will always find it possible to enliven the printed page with many an illustration of value to his students. And the average reader who desires to get a glance at geology and a general notion of its bearings on ordinary life, will find this edition of exceeding interest. It is being used in many schools as a Supplementary Reader, and is admirably adapted for such purpose.

***The following letters show how the book has been received by Teachers of Geology:—***

**Alexander Winchell,** *Chair of Geology and Paleontology, University of Mich.:* I have looked it through with extraordinary interest; for its marked departure from the methods of the old didactic treatises which have done so much to put geology at a disadvantage, in comparison with botany, is in the direction of common sense and in the interests of science and education. I believe the book will have, as it deserves, an extensive use in the schools.
(*July* 23, 1884.)

**Albert A. Wright,** *Prof. of Geology and Nat. Hist., Oberlin Coll.:* I think it is admirably adapted to its purpose, both in matter and style. I have examined only parts of it, but am pleased with the treatment at every point.
(*July* 8, 1884.)

**Jas. M. Safford,** *Prof. of Geology, Vanderbilt Univ.:* I am prepared to endorse it for the purpose and persons intended. Prof. Shaler has treated the subject-matter well and satisfactorily.
(*Sept.* 27, 1884.)

**Edward M. Shepard,** *Prof. of Natural Science, Drury Coll., Springfield, Mo.:* It is by far the best book of the kind that I have seen. (*Sept.* 17, 1884.)

**David S. Jordan,** *Pres. of Indiana Univ.:* From my acquaintance with the author, I have no doubt it will prove thoroughly satisfactory. It is not unlikely that I may use it. (*Oct.* 4, 1884.)

**John C. Branner,** *Prof. of Geology, Indiana Univ.:* With a view to urging the use of some elementary book on geology in the schools of this State, I have examined Prof. Shaler's First Book in Geology. I cannot do better than recommend it. The limited number of subjects treated saves the book from the charges brought against other elementary books which try to teach too much in a short time to pupils not prepared to receive it. The advice to teachers is also very much to the point, and will doubtless be thoroughly appreciated. (*Oct.* 26, 1885.)

**Henry L. Osborn,** *Prof. of Geology, Purdue Univ.:* I am very favorably impressed with the character of the work, and shall take every opportunity of recommending its use. (*Dec.* 3, 1885.)

**H. A. Huston,** *Instructor in Physics, Purdue Univ., Lafayette, Ind.:* I had the pleasure of recommending the book to several Eastern teachers during the summer, and shall call the attention of my successor in the high school here to the work. (*Sept.* 28, 1884.)

**Herbert Osborn,** *Prof. of Entomology, Iowa Agric. Coll.:* I am very much pleased with its plan, and with the contents in general, and deem it well worthy of high commendation.
(*Nov.* 19, 1884.)

**F. A. Chase,** *Dep't of Physical Science, Fisk Univ.:* It is written in a most interesting style, and is much more successful in adapting geological instruction to immature minds than most works of the class. (*Oct.* 11, 1884.)

**Wm. A. Obenchain,** *Pres. Ogden Coll., Ky.:* I am really charmed with Shaler's First Book in Geology. Most heartily do I commend it to the high schools of Kentucky.

**L. M. Underwood,** *Instructor in Geology, Syracuse Univ.:* It commends itself to general use on account of the simplicity with which great truths are

clearly brought before the child's mind, so strikingly in contrast with methods that have been hitherto employed in this subject. (*March* 18, 1886.)

**Dr. Louis Habel**, *Prof. of Natural Science, Norwich Univ., Vt.:* I sincerely wish to see it adopted by all our high schools and academies, for I am convinced that natural science in colleges would become more appreciated by our students than it is at present, with their imperfect education in just these questions of nature. (*April* 5, 1886.)

**George W. Bowman**, *Prof. of Nat. Science, Lebanon Valley Coll., Pa.:* For beginners it is by far the best work I have seen on this subject. The plan and arrangement of the book is excellent. (*March* 13, 1885.)

**J. W. Chickering, Jr.**, *National Deaf-Mute Coll., Washington, D.C.:* I feel impelled to let you know how much I like it, and how well our students have appreciated its clearness and logical arrangement. I shall now look earnestly for the arrival of your larger work. (*March* 19, 1886.)

**Charles O. Thompson**, *late Pres. of Rose Polytechnic Inst., Terre Haute, Ind.:* It is one of the most sensibly written text-books we have. (*Oct.* 6, 1884.)

**N. A. Cobb**, *Teacher of Natural Science, Williston Sem., Easthampton, Mass.:* I have examined it with care, and unhesitatingly say that it is the best text-book on geology, for children, that I have ever seen. The book will do much in helping natural science in effecting its entrance into the common school. The "Directions to Teachers" in the Teacher's Edition are admirable; and, if followed, will enable any live teacher to achieve fair results, whether "up" in geology or not. (*Aug.* 11, 1884.)

**W. C. Collar**, *Prin. of Roxbury Lat. School:* Though my studies lie in other directions, this book is so attractive that it almost persuades me to become a student of geology. (*Sept.* 7, 1884.)

**F. W. Tilton**, *Head Master of Rogers School, Newport, R.I.:* I find it full of interest and of the greatest practical value. It can but accomplish great good by presenting to our youth in a very attractive way knowledge of things about them in nature. I trust that it will be widely read and studied, and that the author will give us other volumes similar in style. (*Oct.* 2, 1884.)

**J. B. Sewall**, *Prin. of Thayer Acad., South Braintree, Mass.:* I think it simply admirable. We have not as yet found place in our course for geology except by lectures, but I shall certainly recommend Professor Shaler's simple and fascinating book to pupils to read and study while hearing the lectures. (*Sept.* 25, 1884.)

**H. T. Pershing**, *Prof. of Nat. Science, Lawrenceville School, N.J.:* It seems to be the right book for beginners, as it makes very clear the similarity between past geological processes and those that any one can see going on now. (*Oct.* 10, 1884.)

**Chas. D. Woods**, *Prof. of Nat. Science, Wesleyan Acad., Wilbraham, Mass.:* I have examined the book somewhat carefully, and am much pleased with it. We shall use it in our classes the present year. (*Oct.* 9, 1884.)

**F. W. Hooper**, *Teacher of Nat. Science, Adelphi Acad., Brooklyn:* I shall recommend its use in the academy. Of all the attempts at making elementary text-books on the natural history sciences this is the most successful. (*Sept.* 29, 1884.)

# *Elementary Course in Practical Zoölogy.*

By B. P. Colton, A.M., Teacher of Science, Ottawa High School, Ill. 5¼ by 7½ inches. Cloth. xiv + 182 pages. Price, by mail, 85 cts. Introduction price, 80 cts.

THIS work is designed to aid the student in getting a clear idea of the animal kingdom as a whole, by the careful study of a few typical animals.

The student is first told how to collect and preserve the material for his study. He is then given detailed directions for its examination and dissection. It is not described for him, thus robbing him of the opportunity to develop his own powers of description, but its parts are named, giving barely enough of description that he may be sure to recognize and apply the proper name to each. He is thus led to observe and describe for himself. His attention is especially called to some of the less obvious points, but explanations are seldom given except when lack of time or ability renders it unlikely that he will prove able to solve the problem unaided.

All the animal sub-kingdoms are represented, more attention being paid to those forms which the student is likely to find. He is led to compare them, one with another, and by noting their resemblances and differences he is shown how to classify animals, rather than taught a system of classification.

The work is limited to what can be done by the average high-school pupil, as proved by the experience of several years during which these guides to the study of animals have been in use.

***The following opinions are from those who have read the work in manuscript or proof:—***

**Alpheus Hyatt,** *Boston Society of Natural History:* The book is a very fine thing. The author knows his subject. (*Dec.* 11, 1885.)

**David S. Jordan,** *Pres. Indiana Univ.* (*author of "Synopsis of Fishes of N. A."*): I have looked over the book with much interest. It strikes me as just the thing for teaching general zoölogy in high schools. I have long since given up zoölogical text-books as a bad job, believing that no book which *could be used without specimens* had any value to the student. This is just the book we need for beginning zoological work in a scientific spirit. I can promise you that we shall adopt it here for beginning classes, and think I shall not be disappointed in it. It will be a great help to me, as to many other teachers of science.

**W. K. Brooks,** *Director of the Chesapeake Zoölogical Laboratory, Johns Hopkins Univ.:* I have examined the Ms. of your proposed book on zoölogy, for use in schools, and I am glad that the author has undertaken to make his experience in teaching natural science available for other teachers, who have not had the special training in this branch of science which he has enjoyed. I am sure that the book will meet with a ready sale, and will be very useful to teachers. (*Dec.*, 1885.)

**S. A. Forbes,** *Prof. of Zoölogy, Univ. of Illinois, and State Entomologist:* It seems to be in every way skilfully prepared, and cannot but be both useful and successful. This is just such a piece of work as has long been needed in public schools.

**Newton Bateman,** *President Knox Coll., Galesburg, Ill. (formerly Supt. of Public Instr. of the State of Ill.)*: If you are able to develop the whole subject with the clearness and charm of these specimen chapters, the result will be a very useful and fascinating book. It will train the faculties of observation to alertness and accuracy. It will bring that deep satisfaction which comes only from original work; from getting first-hand knowledge. It will vitalize the half-dead facts of mere book and memory by the quickening and realistic power of the eye and the hand, directed by keen curiosity and the wide-awake mind. The book is needed. It will be welcomed and appreciated.

**Henry Raab,** *State Supt. of Public Instruc., Springfield, Ill.:* This is a work that presents, for the first time, a guide for the teacher, by means of which he may introduce the pupils to the science successfully, *i.e.*, that they may *like* the study of nature, may prepare for more advanced science work, and gain a lasting benefit for their intellectual development. I shall commend it to teachers of science in our public schools whenever I have an opportunity.

**L. M. Underwood,** *Instructor in Zoölogy, Syracuse Univ., N.Y.:* I am more and more pleased with it as it proceeds. I expect to make use of the book in my classes next fall. (*June* 26, 1886.)

**M. L. Seymour,** *Prof. of Zoölogy, Ill. Normal Univ.:* I have no criticisms. I find the plan, directions, description, and wording excellent. I want to use the book in my classes as soon as published.

**J. H. Pillsbury,** *Biological Laboratory, Smith Coll., Northampton, Mass.:* The plan seems to me to be a very good one for the work for which the author has intended it. I am glad to see so good a plan offered for our high schools. If the remainder of the work is equally good, it ought to be a success. (*March* 19, 1886.)

**E. P. Jackson,** *Teacher of Zoölogy, Boston Latin School:* I think the pages I have examined excellent. All enlightened teachers are aiming at the very standard *in general* which these pages reach *in particular.* If I had a book in my class constructed on precisely this model, I should use it with great confidence and zeal. (*Nov.* 10, 1885.)

**O. S. Westcott,** *Prin. N. Div. High School, Chicago, Ill.:* The book is attractive. I think it would sell with thoughtful teachers.

**J. Y. Bergen, Jr.,** *Prin. of High School, Peabody, Mass.:* I have gone over the manuscript with care, and feel satisfied that there is no American book on zoölogy adapted for use with high-school classes which will enable them to learn so much *at first hand* as they can from this book. It does for the pupil what without it the conscientious teacher must otherwise do for him by constant and laborious reference to the fuller works. (*Jan.* 3, 1886.)

## *How to Find the Stars.*

By Rev. James Freeman Clarke. 4¼ by 5½ inches. Paper. 47 pages. Introduction price, 15 cents.

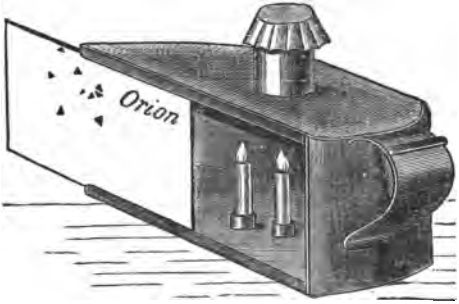
THE object of this little book is to help the beginner to become better acquainted, in the easiest way, with the visible starry heavens; to know the winter and summer constellations, and the principal fixed stars. It shows the position of the constellations at different periods of the year, giving their place in each of the four seasons. It also shows how to find the separate clusters by a series of triangles and diagrams, covering the whole heavens, and connecting each constellation with its neighbors. It indicates the most interesting objects at each period of the year, especially such as can be found with a telescope of moderate power. It closes with a description of the Astronomical Lantern.

## *An Astronomical Lantern.*

Invented by Rev. James Freeman Clarke, Boston. Japanned tin; the face (6½ by 10 inches in size) is of ground glass, behind which lights may be placed. Thirty-two constellations are photographed upon seventeen slides of semi-transparent card-board, and stars of four magnitudes are represented by perforations of proper size. The maps have been prepared under Dr. Clarke's personal supervision, and the plates, being photographed from the original drawings, are correct in every particular. The former price of the Lantern was $6.00; we now offer it, in improved form, with the slides, and a copy of "How to Find the Stars," for $4.50. The whole carefully packed in a wooden box, with sliding cover.

THE object of this useful piece of apparatus is to facilitate the study of stellar astronomy. It is intended for beginners in astronomy in schools and in families, and, in fact, for all who desire to become acquainted with the constellations.

The difficulty hitherto experienced in this study, and which is obviated by the use of the lantern, is this: In order to study the starry heavens, it has been necessary to use an astronomical atlas or a celestial globe. These must be examined in the house, by the light of a lamp. The observer, having found his constellation on the atlas, goes out to look for it in the sky. But by the time he gets out of doors, he has forgotten how it looked on the atlas. And when he has found it in the sky, he forgets how it looked there, before he gets back to his atlas or globe.



Now, the astronomical lantern makes the study of the stars perfectly simple and easy. It is constructed like a dark-lantern, closed on three sides, and on the fourth provided with a ground glass, in front of which maps can be inserted. On each of these maps, which are semi-transparent, is represented a constellation, the places of the stars being indicated by perforations, through which the light shines. The largest perforations are for the stars of the first magnitude, and the smaller, in due proportion, for the lesser stars. The student, therefore, wishing to observe any particular constellation or cluster, has only to light a candle within the lantern, insert the appropriate slide, and go out into the night. Holding up the lantern in one hand, he can compare the constellation as it appears on the lantern with that in the sky, until he becomes perfectly familiar with the latter.

It is easy to see how much the use of such a lantern facilitates the whole study. In fact, we think that henceforth no one wishing to become acquainted with the heavens can afford to dispense with it. The increased ease of the study should also enlarge the number of students in this interesting department of science.

***The following testimonials as to its value have been recently received:—***

**C. A. Young**, *Prof. of Astronomy, Princeton Coll.:* I find it to be an admirably contrived apparatus for its purpose, —simple, easily managed, and effective. I think an adequate knowledge of the constellations could be obtained by its use, in connection with the little book that accompanies it, more rapidly and easily than from the most elaborate and expensive celestial globe. (*Aug.* 8, 1885.)

**C. S. Lyman,** *Prof. of Astronomy, Yale Coll.:* It is certainly a very simple and happy device for facilitating the study of the stellar configurations, and aiding the student in familiarizing himself with the nightly aspects of the heavens. The mere study of the constellations, is, indeed, but a small part of astronomy, yet a part both interesting and important to the beginner; and I have never known any contrivance that could compare with this Lantern for saving alike time, trouble, and eye-sight, and rendering such study attractive and easy. It is such a device as the writer well remembers often desiring, and even purposing to construct, yet never brought to pass. Schools, academies, colleges, and amateur astronomers cannot fail to find it useful, and all who use it will feel thankful to Dr. Clarke and his publishers for putting so convenient a piece of apparatus within their reach. (*Dec.* 15, 1885.)

**O. C. Wendell,** *Harvard Coll. Observatory:* I find it well adapted to its purpose. It combines in a high degree simplicity with clearness, and, for beginners and amateurs, I think it has no equal. The diffused light transmitted through the cardboard enables one easily to see the printed magnitudes, as well as letters and constellations. Mr. Clarke seems to have done a real service to the youthful patrons of astronomy in devising a lantern which is at once portable, highly entertaining, and so cheap as to be within the reach of all. I am confident that the names of the principal stars and constellations can be learned from it in half the time required to learn them from an ordinary map. (*Nov.* 18, 1885.)

**C. Getchell,** *Science Teacher, Phillips Exeter Academy:* I consider it the best means for enabling students to identify in the heavens those stars which they have studied from a map or globe. In the recitation-room it shows to the whole class the constellations in the positions in which they appear in the sky. In case the teacher does not have the opportunity for much out-door work, good results are obtained by requiring each pupil to make a set of perforated maps from his own observations. These maps may be verified by comparison with those furnished with the Lantern. (*June* 29, 1885.)

**E. H. Rudd,** *Science Teacher, St. Mary's School, Knoxville, Ill.:* I have used it for two years, and find it of the greatest practical benefit to my classes in astronomy. There is nothing that I know of which could take its place. The interesting part of astronomy to most pupils is learning the names, form, and location of constellations. My experience is, that the Lantern, for this purpose, is worth a dozen globes or charts. Nothing, to my mind, is better than the system of triangulation as a help to location. (*Aug.* 1, 1885.)

**R. W. B. Elliott,** *San Antonio, Tex.:* I have found it very useful in arousing the interest of my children, and enabling them to identify the different stars and constellations. It furnishes a very pleasant and instructive means of passing the earlier part of our bright Texas nights. (*July* 27, 1885.)

**Mary A. Brackett,** *Prin. Private School, Brooklyn:* I think it by far the best thing of the kind I have ever seen. Any beginner in the study of practical astronomy could not fail to derive great pleasure and help from it. Its simplicity gives it its greatest charm. (*Aug.* 8, 1885.)

**Clement B. Smyth,** *New York:* One which I purchased for my daughter has been of great interest and aid to her in her studies. It is an apparatus which, if known to those interested in this study, would, I should think, be very frequently called for. My daughter is delighted with it, and feels greatly indebted to her teachers, who kindly advised her of its value, and where to procure one. (*July* 27, 1885.)

# SCIENCE.

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*An Introduction to the Study of the Compounds of Carbon.* By IRA REMSEN, Professor of Chemistry, Johns Hopkins University, Baltimore. x + 364 pages. Cloth. Price by mail, $1.30; Introduction price, $1.20.

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*Descriptive and Qualitative.* By JAMES H. SHEPARD, Instructor in Chemistry in the Ypsilanti High School, Michigan. xxii + 377 pages. Cloth. Price by mail, $1.25; Introduction price, $1.12.

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